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Abstract

In this paper we study the premiums between the prices of a stock traded both "spot"—*ie* with rolling $(t + 3)$ settlement—and "forward" (settlement at the end of the half-month), as was the practice in Brussels until 1997. We first test for settlement effects, *ie* pure time-value explanations, and find that these are theoretically small and empirically almost undetectable, despite the potentially high power of our tests. Experimenting six arbitrage trading rules to seek for an explanation of what else might behind the price differences, we find a clue in the autocorrelation of the premiums: positive premiums tent to persist while negative ones do not. The persistence is too weak to allow profitable low-risk 'arb' trading, but the pattern still suggests that there is a 'cash is king' effect: sellers tend to prefer spot sales, and buyers tend to go for forward purchases. This is consistent with the idea that the cost of financing consists of not just pure time value but also of a fixed shadow cost (reflecting the hassle and delays caused by raising cash), and that this cost is larger and arises more often and more persistently than the hassle costs of shorting stocks.

JEL G14, G15

Key words: dual markets, price discovery, settlement effect, microstructure

Time Value in Spot and Forward Prices on the Brussels Stock Exchange

Introduction

Until 1997, the most active of the Brussels-listed stocks were traded both "spot"—*ie* with rolling ($t + 3$) settlement—and "forward" (settlement at the end of the half-month). Both segments were order-driven, and their opening prices were set via a call. So there were no firm bids and asks, implying that the usual no-arbitrage predictions about price differences should be weakened into statements about expectations. In studying the premiums between the forward and spot prices we first test for settlement effects, *ie* pure time-value explanations. Our finding however is that these are theoretically small and empirically almost undetectable, despite the potentially high power of our tests. Seeking for an explanation of what else might behind the price differences, we find a clue in the autocorrelation of the premiums: positive premiums tend to persist while negative ones do not; in fact, surprisingly often, negative premiums are followed by positive ones. The persistence is too weak to allow profitable low-risk 'arb' trading, but the pattern still suggests that, within these no-arb bounds, there is a 'cash is king' effect at work: sellers tend to prefer spot sales, and buyers tend to go for forward purchases. This is consistent with the idea that the cost of financing consists of not just pure time value but also of a fixed shadow cost (reflecting the hassle and delays caused by raising cash), and that this cost is larger and arises more often and more persistently than the inconvenience costs of shorting stocks.

In the remainder of this introduction we briefly review the literature on settlement effects; we explain how Brussels data could be useful here; and we specify the research questions and the results.

A large numbers of empirical studies have been devoted to examine the settlement effect in stock markets. These papers investigate either a day-of-the-week effect in the fixed-settlement-lag procedure as in the US, Japan, Canada, Australia, or a day-of-the-settlement-period effect in the fixed-settlement-date procedure as in the U.K., France, Italy, Switzerland, and Belgium.

While the day-of-the-week effect is "too small to be detectable",[1] the findings for the fixed-settlement-date procedure are mixed.[2] All of these studies are hampered by a power issue when testing the time-value effect in stock returns. In markets with a fixed-lag delivery system, the variation of the time-value is very low because it stems from the two extra days of interest due to the weekend. In the fixed-date markets, the time-value has higher variability as there is a substantial change in time to maturity between the last price of a settlement period and the next day's price. If we can find stocks that are simultaneously traded on both systems, an even more powerful test would be possible: investigate the time-value effect in price discrepancies using the cross market data. As we show, this offers both a higher variation in the time value and a regression error with lower variance. The Brussels Stock Exchange (BSE) was one of the few markets that had both spot (fixed-lag) and forward (fixed-date) trading tiers, which allows us to investigate the time-value effect more efficiently.[3]

A companion paper addresses the issue as to which market was noisier, that is, which acted as the price discoverer, during the period 1989-1996. In this paper we study the behavior of the spot-forward price differences or the forward premiums as they emerged, *ex-post*, from the opening call. There are two issues of interest. First, we would expect a statistically clear time-value or settlement effect in the forward premiums, stronger and statistically more detectable than the settlement effects one expects in either spot or forward returns. The second issue is whether the forward premiums are consistent with the notion of market efficiency. If prices are unpredictable, then so should be price differences across markets; and any observed predictibilities should still be bounded by 'arb' transaction costs and have an acceptable economic rationale.

Our results on settlement effects are mixed, at best. In the spot market we actually see very little evidence in favor or against a time-value effect, consistent with our priors on the power of the tests. In the forward markets, where the time value signals should be stronger, we do find that time value affects prices, but the effect is substantially smaller than what theory predicts. As expected, time value is noticeable in forward premiums, but even there

[1] Solnik(1990)

[2] Solnik (1990), and Crouhy, Galai and Keita (1991) document such an effect for the French market. Solnik (1990) finds that the stock market index behaves as predicted, but on the individual-stock level Crouhy, Galai and Keita (1991) find evidence of overreaction, especially for thinly traded securities. Jaffe and Westerfield (1985) and Condoyanni, O'Hanlon and Ward (1987) report anomalous results for the London market.

[3] In Paris, in some periods, stocks were traded with either fixed or rolling settlement, never both. Basel had parallel markets.

the estimates remain below our theoretical priors.

Next, we move to the (un)predictability of forward premiums. We find that forward premiums are anomalously autocorrelated. This then raises the question why traders do not react to these predictable price anomalies. We then experiment with six arbitrage trading rules to test whether it is possible to exploit this result, that is, whether we would make money if, whenever the forward is too high relative to the spot price, we place market orders for a spot purchase and a forward sale at the next opening, and *vv.* We find that the predictability is too weak - relative to costs - to generate attractive 'arb' opportunities. More revealingly, there is an asymmetry: the abnormal forward premiums that tend to peter out slowly are the unusually positive ones, while abnormally negative ones on average almost vanish overnight. In addition, large positive forward premiums are over two times more frequent and larger than negative discrepancies. This pattern is the opposite of what one would expect if the problem had been a lack of shortselling in the spot market. Instead, the anomaly suggests problems with raising liquidities, steering buyers towards the forward market and sellers to the cash market, thus creating episodes of persistently high forward premiums.

The rest of the paper is organized as follows. Section 1 describes the markets and the data. In Section 2 we start from a standard noisy-price model and derive, discuss, and perform alternative tests for settlement effects in, respectively, spot returns, forward returns, and forward premiums. Section 3 provides the tests for autocorrelation. The pattern that emerges suggests that the price discrepancies are not related to difficulties in going short but rather to simple financing considerations. Section 4 concludes.

1 The Two-Tier Brussels Stock Exchange: Institutional Background

Brussels used to have not only its own stock market (the Brussels Stock Exchange (BSE), integrated into Euronext since 2001), but even a two-tiered one: a "spot" market tier with third-day delivery, and for the most active stocks a parallel "forward" tier with fixed-date delivery. There used to be twenty-four fixed settlement dates per year, implying that the trading periods typically lasted about two weeks, hence their name *quinzaine*, two-week period.[4]

[4] The forward market has now disappeared, following a "$T \leq t + 7$ days" rule implemented internationally in the 1990s. London used to have a two-weekly fixed-delivery system too: Paris had delivery at the end of the month in its "forward" section for big stocks. (There also was a spot section for small stocks). Basel offered the

Details about the market organization are crucial for our analysis. In this section, we describe the price mechanisms in the forward and spot market and the delivery rules as they applied during the sample period.

1.1 The price mechanism in the forward tier

The forward market used to work via a pure public limit order book (which, during the sample period, was kept by a version of Toronto's Computer-Aided Trading System, CATS). Thus, although brokers were allowed to trade on their own account, they did not act as market makers, and their main role on the floor was to pass on the orders from the public to the exchange. At 9 p.m., the one-hour pre-market started, during which orders could be added or withdrawn and CATS displayed a continuously updated preliminary market-clearing price. Actual trading in the forward market started at 10 a.m., with a simultaneous call market for all stocks. That is, at 10 a.m. limit orders were matched as far as possible, and executed. For most stocks the opening represented a substantial part of the day's turnover. After the opening round, the interactive trading session or "continuous market" started (10:00-16:30). Throughout the continuous-market session, the four best unfilled limit orders on the buying and selling side were displayed on computer screens and could be taken up by any incoming new order. Only brokers saw the screens: at the time of the sample, individual investors just heard (or saw) the opening and close prices over the radio or on Teletext, at noon or in the afternoon. Orders could also be matched directly, between brokers or in-house, provided that the price was within the book's bid-ask spread and the trade was reported immediately to the exchange. Large trades, *i.e.* blocks of at least BEF 50m (EUR 1,250,000) could be crossed or traded outside the BSE (often in London or Paris), but had also to be reported immediately. There were no limits on consecutive forward price changes. Limit order and trade prices were rounded according to a schedule shown in Table 1. Until the 1996 reform, the exchange's minimum margin requirement for a forward trade was 25 percent, but the BSE left the enforcement of this rule to the individual brokers (who bore the default risk). Securities could be posted as margin; in fact, many investors left most or all of their stocks with a their broker—most shares are bearer securities—and used this portfolio as margin for forward positions. Thus, there was no opportunity cost associated with the margin.

Prices for all traded lots were shown, in sequence (but not time-stamped), in the official

choice between several delivery dates.

Table 1: **Tick Size in the Spot and Forward Market**

price range	price must be a multiple of	minimal percentage price change at lower end of scale	minimal percentage price change at top end of scale
BEF 1-500	1	100%	0.20%
BEF 502-1,500	2	0.40%	0.13%
BEF 1,505-5,000	5	0.33%	0.10%
BEF 5,010-10,000	10	0.20%	0.10%
BEF 10,025-50,000	25	0.25%	0.05%
BEF 50,050	50	0.10%	—

Key One BEF is approximately EUR 0.025.

price list, a function later taken over by the financial dailies, *De Tijd* and *L'Echo de la Bourse*. In the electronic records, only open/close/high/low are available.

1.2 The Spot Price Mechanism

Due to its lower volume, the spot market was fully computerized much later (in 1996). Like the forward tier, it was order-driven but the implementation was more artisanal. First, there was no pre-market, so that the opening price was potentially much more subject to noise than the forward opening price even apart from volume effects. Second, because of the thinness of the market, for many stocks there was just one trading round per day; this subsegment of the spot market was called the '*parket/parquet*' market. A continuous market existed only for the more active stocks (quoted on the *"corbeille"* subsegment) and even this continuous market was not very active.[5] Third, there was no centralized public order book kept by the exchange. Rather, a few specialist brokers each kept their own books, and met sometime between 1 p.m. and 1.30 p.m. on the Exchange's floor to aggregate their information and identify the price that maximizes trade from the combined order book. Fourth, for stocks that were not traded on the parallel forward market, there were daily price limits of 5 percent (for very thinly traded stocks, traded on the *parket* segment) or 10 percent (for other stocks, traded on the "*corbeille*" market). And, in the *corbeille* market, subsequent intraday price changes could not exceed 5 percent.

The actual pricing and trading was organized by a BSE official who started by crying out a price proposal. This price proposal equaled the price that maximized trade from the order book if that price was within the price change limits. If not, the official announced the price limit itself. In addition to the price proposal, the official also announced the direction of the imbalance. If there was an excess supply (demand) at the proposed price, additional purchase (sale) orders from the floor were solicited to reduce the imbalance in the book. If the remaining imbalance between supply and demand at the price limit was less than 50 percent, the specialist would decide to 'reduce' most or all orders on the excess side, *i.e.* execute only part of each order. The transaction price was then published in the financial press with the qualification *"sellers reduced"* or *"buyers reduced"*. If, at the price limit, the imbalance between supply and demand remained huge, even after soliciting orders from the floor, there was no trade at all and the price limit was published as an indicative price. In practice, however, when the imbalance was only slightly larger than 50 percent, the stock's specialist brokers often added purchase or sale orders for their own account to prevent no-trade (and no-income) days.

[5] *Corbeille*, meaning 'basket', refers to the tables with an unusual basket-like basis that were in that part of the floor. Parquet refers to the wooden floor covering.

As, around 1990, the spot market list contained about 300 stocks, the stock-by-stock opening-call prices were set more or less sequentially. The exact timing of each stock's spot fixing was not registered.

As mentioned, the spot market had two sub-tiers. For about half the stocks, those listed on the *parket* market with its less liquid stocks, the call was also the only price for that day. For stocks quoted on the *corbeille*, the fixing was followed by the traditional (blackboard-and-chalk) version of the continuous market: unfilled orders were chalked onto the blackboard and could be picked up from the floor, and orders could also be matched directly on the floor at a price within the book's spread. For the *corbeille* market, prices for all traded lots were shown, in sequence (but not time-stamped), in the official price list but in the electronic records, only open/close/high/low are available. For the *parket* stocks there is just the single price.

1.3 Settlement Rules

For the BSE, the other details of the actual settlement were similar for both market tiers. The buyer paid via a bank transfer rather than by check. This means that there was no "mail float" on the payment side. Still, the value dates for buyer and seller did not match perfectly: the buyer's value date is one day before the actual settlement day and the seller obtains value one day after settlement.

Delivery of the stock could mean actual physical delivery of the piece of paper, if the buyer desired so. Alternatively, the buyer could ask that his or her purchase be recorded with a netting and depository institution, the *Caisse Interprofessionelle/Interprofessionele Kas* (CIK). The CIK merely netted the physical deliveries across brokers if actual delivery is asked and held the paper on behalf of investors who did not demand physical delivery. Thus, the CIK was not a clearing house in the usual sense: it did not act as a central counterpart, nor did it cancel an individual investor's earlier purchases against subsequent sales (or *vice versa*) within one settlement period. There was some informal clearing by brokers, though: brokers did not exact delivery and payment for a forward transaction that was reversed later on via the same brokerage house and within the same quinzaine.

One function of the forward market, therefore, was to reduce the cost and hassle of mutually offsetting stock deliveries and payments for trades that had been closed out within the same quinzaine. This partly explains why, unlike in currency markets, the transaction costs for small trades in the forward tier were somewhat lower than in the spot tier (as illustrated in Table

Table 2: **Transaction costs, spot and forward, 1990**

item	cost of spot trades	cost of forward trades
+) BSE Commission	max(tradesize×0.03%, BEF 6 000)†	
+) Transaction Tax	max(tradesize×0.17%, BEF 10 000)	
+) Brokerage fees:		
- fixed part	BEF 200*	
- variable part:		
order BEF 1-5m	1%	.8%
order BEF 5m-10m	.8%	.6%
order BEF 10m-20m	.4%	.3%
order BEF 20m-30m	$\geq$ BEF 130 000‡	.2%
order $\geq$ BEF 30m	$\geq$ BEF 130 000‡	$\geq$ BEF 120 000‡

† : 40 BEF is worth approx. 1 EUR; * : plus BEF 100 for the buyer if physical delivery is asked; ‡ : negotiable, with the stated amounts as minima. Thus, around 1990 a rather small trade of BEF 250,000 (approx. EUR 6.250) would cost 1.29 percent spot, and 1.09 percent forward. For an order of BEF 30m (750,000 Euros), the cost difference may be as small as 10,000/30,000,000 = .033 percent.

2).[6] A second useful feature of the forward tier is that it allows one to take short positions until the end of the *quinzaine*, positions that could then be rolled over fairly easily. In Belgium, there was no formal legal framework for asset borrowing and spot short-selling until the 1991 Financial Market Reform Act, and even then the only organized facility was the opening by the central bank of a lending facility for Government bonds, accessible to the prime brokers who distribute and quote the bonds. For stocks, shorting in the cash market meant (and means) finding one's own asset lender; even nowadays, prime brokers might only be willing to help for big orders in big stocks. In short, the forward market provided the sole organized opportunity for short positions.[7] A third function of the forward market was to provide the equivalent of buying on margin: the actual payment was deferred until the end of the *quinzaine* (at which moment the forward contract could be rolled over) and the buyer just posted the 25 percent security. Since leveraged buying was possible in the forward market, no organized system of buying on margin was set up in the spot market.

[6]Another reason for the lower transaction costs might have been the fact that the forward market had vastly larger volumes than the spot market for the same stock, see below.

[7]There was even a centralized mechanism for asset lending in the forward market if, at the end of the *quinzaine* one wanted to roll over a short position. The solution was to borrow a stock (for delivery under the maturing contract), and to buy it back for the new forward date. Finding a lender happened in an organized session on the day of the *prolongations*. The agents settles his gain or loss, the difference of the initially contracted price and the settlement price at 1:30 p.m. on the last day of the *quinzaine*, and also pays the time value until the next settlement day. In return he holds a new contract at the settlement price.

1.4 Possible clientele and differential information aspects

It is fair to say that the organization of the forward markets was superior: it was fully computerized, and therefore faster, already by the late 80s; had a pre-market that revealed the market consensus and reduced the impact of accidental imbalances that would otherwise have plagued the opening call; enjoyed lower costs and no price limits; and was much deeper. Figure 1 reports the eight-year mean of the volume ratio, forward to spot, for each stock. Note that the 71 selected stocks are ranked from low to high ratio. We see ratios going from 2.5 to 250; more fairly perhaps, when stocks are put into three relative-volume buckets, each of 24 stocks, the average relative volume per bucket goes from about 10 to 50.

In addition (or, perhaps, as a result of the above), conventional wisdom within the financial community held that there also was an clientele- and efficiency-related form of segmentation.[8] Indeed, because of its shorting facilities and the absence of price limits, the forward market had a somewhat more speculative reputation, to the extent that conservative firms (such as the major banks) have long resisted a forward listing. Because of this speculative image, the forward market was considered to be the market for the more professional agents, while less sophisticated investors were said to prefer the spot market. Having no systematic and fast access to news during working hours, these amateur traders allegedly reacted slower than the professionals. In the terminology of Garbade and Silber (1983), this view hypothesizes that the forward market was the price discoverer, while the spot market was just a (lagging) satellite market. This hypothesis is the central issue of the dissertation.

We conclude the descriptive section with some information on the data.

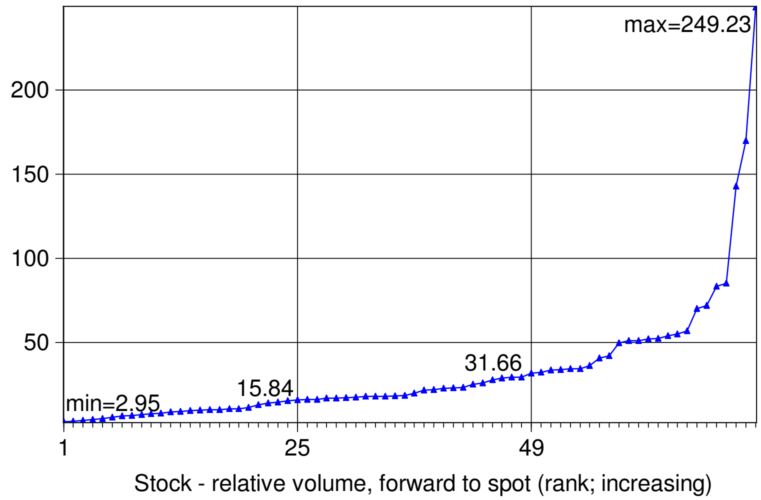
1.5 Data Description

The sample period starts in early 1989, at which time the forward market was fully computerized, and it ends in 1996. In 1997, the forward market disappeared. Euronext's historic-data CDs for that period include the opening spot price per day, and, for the forward market, the daily opening, high and low, and close price. Data on dividends, bonus dividends, splits, and rights issues[9] were missing, and were hand-collected from *Memento der Effecten*, a trade pub-

[8] We are indebted to the late Prof. Van Essche for this suggestion.

[9] A subscription right is represented by a coupon designated for the purpose and it is traded separately the moment the stock goes ex this coupon. The market values of these "scripts" are very noisy so we worked with

Figure 1: **Mean of Volume Ratio, Forward to Spot**



lication, and from *De Tijd*, which published the Dutch-language version of the Official Price List. For the risk-free rate, we used the Euro-BEF 1 week middle rate from Datastream.

We discarded foreign stocks, about half of the list, since price discovery for these shares probably happens abroad anyway. So we started from data on 119 Belgian stocks traded on both the spot and forward tiers of the Brussels Stock Exchange during the period 1989-1996. Some data cleaning was required: 16 stocks are excluded due to an insufficient number of observations (too many missing data points), 31 stocks are connected to other shares due to a change in the name or code after a stock split or merger. Thus, 72 stocks remain. All unusually large forward premiums or large changes in the prices were double-checked with the prices posted on the hard copies of *De Tijd*, including the next-day rectifications for typos. All prices that are indicated 'sellers reduced', 'buyers reduced', or 'indicative', were considered to be missing observations. Whenever there is a missing price, the two returns that are associated with that price are missing too. That is, we never use cumulated returns straddling some missing price.

As the risk-free rate we used the one-week call-money rate and the [calendar days]/360 time convention that then applied outside the interbank market for BEF.

We mainly use the opening prices for our empirical analysis. We would have liked to work

the standard instrinsic value of a subscription right.

Table 3: **Trading Frequency and One-day Return Variance across Turnover Classes**

sample (by turnover)	Number of Returns Spot	Number of Returns Forward	Average Variance Spot	Average Variance Forward	Median Variance Spot	Median Variance Forward
All	95,668	87,957	3.26	3.43	2.23	1.91
Low turnover	27,605	21,772	4.55	5.17	2.77	2.11
Medium turnover	31,192	29,324	3.23	3.12	1.92	1.66
High turnover	36,871	36,861	1.99	2.00	1.61	1.88

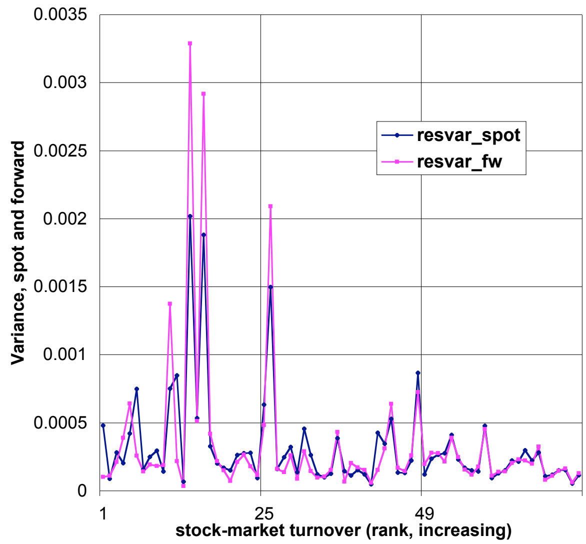
Key: Each turnover class contains 24 stocks, and ranking is done on the basis of average daily turnover.

with the close prices too, but for unknown reasons, close prices are missing quite often. Eight years of data means over 2000 trading days. The number of effectively available observations is very variable, ranging from below 50% to 100%. There is a clear relation with the market activity. As can be seen in Table 3, the firms in low-, medium-, and high-turnover groups on average trade 55, 62, and 74 percent of the time, respectively, in the spot market. In the forward market, the corresponding numbers are 43, 58, and 74 percent. Forward markets more often have missing prices than spot markets despite their higher turnovers and the absence of price limits. This probably reflects the interventions by the spot market's specialists mentioned in Section 1.2. There is also a strong negative relation between turnover and return variance, *prima facie*, as also illustrated via Figure 2. Much of that, however, seems to be due to the outliers: when we consider medians, the schedule is much flatter.

By way of caveat, note that the variances in the text table offer just a rough first picture. It ignores, for instance, the fact that the spot market was active on more days than the forward tier, and that days where the forward market did not manage to reach equilibrium may also have been unusually illiquid and noisy days in the spot market.

An extensive Appendix contains more details about the sample, including the list of stocks, and, per stock, the period of listing, numbers of potential and actual prices of all kind (incl buyers/sellers reduced, indicative prices, etc.). This is provided for each market separately, and then for the intersection, ie the sample where both markets have reliable prices.

Figure 2: **Variances of daily returns, spot v forward; opening prices, all days**

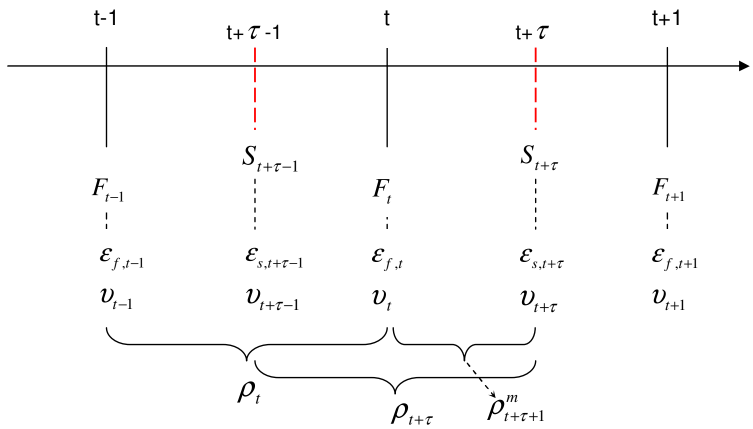


2 Verifying the Settlement Effect in Prices in Well Integrated Markets

The fixed-lag and periodic settlement systems, as adopted by the spot and forward markets, respectively, should each generate a specific type of seasonal in the observed stock returns. In the fixed-date ('forward') markets, consecutive prices within one settlement period are essentially forward quotes with decreasing times to maturity, as shown in Table 4 below. It follows that, within a given settlement period, the percentage price change corresponds to an (unobservable) spot return minus approximately the daily risk-free rate.[10] That is, percentage price changes within a given settlement period should tend to be below the general average return. On the other hand, there is a substantial change in time to maturity between the last price of a settlement period and the next day's price. Therefore, the percentage change that straddles two adjacent settlement periods should consist of a true spot return plus two weeks' (London) or one month's (Paris) worth of time value, and tend to be above the general average return. Solnik (1990), and Crouhy, Galai and Keita (1991) document such an effect for the French market. Solnik finds that the stock market index behaves as predicted, but on the individual-stock level Crouhy, Galai and Keita find evidence of overreaction, especially for thinly traded securities. Jaffe and Westerfield (1985) and Condoyanni, O'Hanlon and Ward

[10]This claim is exact only if riskfree rates are constant across maturities and over time.

Figure 3: **Asynchronism of Spot vs Forward Prices**



Key: t is at 10 a.m. and $t+\tau$ is at 1:30 p.m.

(1987) report anomalous results for the London market.

Spurious seasonals caused by time-value effects should also be observed in markets with a fixed-lag delivery system. As 'days' refer to working days rather than calendar days, any intervening weekend or holiday should lead to time-value effects in prices. As Solnik (1990) notes, there is often a day-of-the-week effect but its size is:

> *"... usually much larger than the expected effect of the settlement procedure, and often does not take place on the expected day.*[11] *This implies that the observed day-of-the-week effect is explained by other phenomena and that the influence of the settlement procedure is too small to be detectable without a precise model of these other phenomena."*

McFarland, Pettit, and Sung (1982) study foreign exchange markets (where, with a few exceptions, a second-working-day rule applies). For the Vienna stock market, Gruenbichler (1991) reports anomalous seasonals that substantially exceed the effects of time value.

We first turn to the tests of settlement effects. In Section 2.2 we will discuss the pros and cons of tests that rely on time series of either spot returns or forward returns, relative to tests on forward premiums. Section 2.3 introduces the way we obtain average coefficients. Results follow in Section 2.4.

2.1 The Model

Let v_t denote an unobservable true value, based on full and correct use of all relevant available information, expressed as a price for immediate payment and delivery. Since neither the actual spot nor the forward prices imply immediate settlement, the corresponding true "spot" and forward values, denoted as s and f, should contain a settlement effect shown below, with n_s and n_f denoting the number of calendar days to settlement and R the simple *per diem* interest rate. In addition, actually observed prices are assumed to deviate from true values by a zero-mean, i.i.d. noise term, denoted by ϵ_s or ϵ_f, respectively, which reflects unanticipated orders by liquidity traders and noise traders, as standard in microstructure models:[12]

$$\begin{aligned}
\text{noise-free prices: } s_{t+\tau} &= (1+n_{s,t}R_t)v_{t+\tau}, && (1)\\
f_t &= (1+n_{f,t}R_t)v_t, && (2)\\
\text{observed prices: } S_{t+\tau} &= s_{t+\tau}(1+\epsilon_{s,t+\tau}) = v_{t+\tau}(1+n_{s,t}R_t)(1+\epsilon_{s,t+\tau}), && (3)\\
F_t &= f_t(1+\epsilon_{f,t}) = v_t(1+n_{f,t}R_t)(1+\epsilon_{f,t}). && (4)
\end{aligned}$$

with $\mathrm{E}_{t^-}(\epsilon_{s,t+\tau}) = 0 = \mathrm{E}_{t^-}(\epsilon_{f,t})$; t^- a short time before t; time t is 10 a.m., the opening of the forward market; time $t+\tau$ is 1 p.m, the opening time of the spot market.

These models are not ready for use as such since they contain unobservable prices. The standard way to make such models tractable, in the sense of being able to identify some key parameters, is to consider returns—percentage changes in S or F, as is done below. In (5) and (7), the true values have been combined into a true return, denoted as ρ_t, which is then assumed to be unpredictable white noise. We also introduce the shorthand notation $\Delta n_s R$ and $\Delta n_f R$ to indicate the settlement effect in a spot or forward returns, and e to indicate $\ln(1+\epsilon)$. Therefore, for the continuous spot market we have:

$$\begin{aligned}
r_{s,t+\tau} &:= \ln\left(\frac{S_{t+\tau}}{S_{t+\tau-1}}\right),\\
&= \ln\left(\frac{1+n_{s,t}R_t}{1+n_{s,t-1}R_{t-1}}\right) + \ln\left(\frac{v_{t+\tau}}{v_{t+\tau-1}}\right) + \ln(1+\epsilon_{s,t+\tau}) - \ln(1+\epsilon_{s,t+\tau-1}), && (5)\\
&=: \Delta(n_sR)_t + \rho_{t+\tau} + e_{s,t+\tau} - e_{s,t+\tau-1}, && (6)
\end{aligned}$$

---

[11] See *e.g.* Lakonishok and Levi (1982), Jaffe and Westerfield (1985).

[12] We ignore the time value of half a day as interest is calculated per entire day only.

and likewise, in the forward tier,

$$\begin{aligned} r_{f,t} &:= \ln\left(\frac{F_t}{F_{t-1}}\right), \\ &= \ln\left(\frac{1+n_{f,t}R_t}{1+n_{f,t-1}R_{t-1}}\right) + \ln\left(\frac{v_t}{v_{t-1}}\right) + \ln(1+\epsilon_{f,t}) - \ln(1+\epsilon_{f,t-1}), \qquad (7) \\ &=: \Delta(n_f R)_t + \rho_t + e_{f,t} - e_{f,t-1}. \qquad (8) \end{aligned}$$

2.2 Competing Test Equations for Settlement Effects: pros & cons

We consider four test equations, each with its pros and cons. The first two are our earlier expressions for the spot and forward returns, equations (6) and (8). The third test equation is the difference of the returns which, because of the overlap in the afternoon, boils down to the difference between the two morning returns (10 a.m.-1:30 p.m.). The fourth focuses on the forward premium, $\ln(F/S)$, and is obtained by subtracting the two log-price equations, the logs of (3) and (4):

$$\begin{aligned} r_{s,t+\tau} &= \Delta(n_s R)_t + \rho_{t+\tau} + e_{s,t+\tau} - e_{s,t+\tau-1}, \qquad (9) \\ r_{f,t} &= \Delta(n_f R)_t + \rho_t + e_{f,t} - e_{f,t-1}, \qquad (10) \\ r_{f,t} - r_{s,t+\tau} &= [\Delta(n_f R)_t - \Delta(n_s R)_t] + [\rho_t - \rho_{t+\tau}] + [e_{f,t} - e_{f,t-1}] - [e_{s,t+\tau} - e_{s,t+\tau-1}], \\ &= [\Delta(n_f R)_t - \Delta(n_s R)_t] + [\rho_t^m - \rho_{t+1}^m] + [e_{f,t} - e_{f,t-1}] - [e_{s,t+\tau} - e_{s,t+\tau-1}], \qquad (11) \\ p_t &:= \ln\left(\frac{F_t}{S_{t+\tau}}\right) = \ln\left(\frac{1+n_{f,t}R_t}{1+n_{s,t}R_t}\right) + \ln\left(\frac{v_t}{v_{t+\tau}}\right) + e_{f,t} - e_{s,t+\tau}, \\ &= \Delta(n_s^f R)_t - \rho_{t+1}^m + e_{f,t} - e_{s,t} \qquad (12) \end{aligned}$$

where r is the observed return (or percentage price change, including any coupon detached between $t-1$ and t); $\Delta(nR_t)$ is the theoretical settlement effect in the left-hand-side variable;[13] ρ_t and $\rho_{t+\tau}$ are the one-day true returns and ρ_t^m is the true return in the morning (10 a.m.-1:30 p.m.); e_t is the percentage noise added in the time-t price. One can, therefore, regress each of the left-hand-side variables on its associated theoretical time value and test for a unit regression coefficient, treating both the true return and the micro-structural noise terms as a

[13]Specifically, for the spot returns $\Delta n_s R_t$ equals $\ln[(1+n_{s,t-1}R_{t-1})/(1+n_{s,t}R_t)]$ where $n_{s,t}$ is the number of calendar days between date t and the settlement date, and R_t the per diem interest rate. For forward rates the definition is analogous. For forward premiums, it equals $\ln[(1+n_{f,t}R_t)/(1+n_{s,t}R_t)]$.

Table 4: **Variability of the Time to Settlement over a Representative Two-week Trading Period, and actual sample sigmas**

	Representative two-week trading period: characteristics											actual $(\Delta)n_x.R$	
	Mon	Tue	Wed	Thu	Fri	Mon	Tue	Wed	Thu	Fri	stdev	mean	stdev
n_s	3	3	5	5	5	3	3	5	5	5			
n_f	16	15	14	13	12	9	8	7	6	5			
Δn for r_s	-2	0	2	0	0	-2	0	2	0	0	1.33	0.000	0.027
Δn for r_f	11	-1	-1	-1	-1	-3	-1	-1	-1	-1	3.92	-0.000	0.100
Δn for r_f-r_s	13	-1	-3	-1	-1	-1	-1	-3	-1	-1	4.64	-0.000	0.100
Δn for p	13	12	9	8	7	6	5	2	1	0	4.42	0.149	0.112

Key: The table refers to two normal trading weeks. Line one shows the number of calendar days to settlement in the spot market: three in the beginning of the week, jumping to five as of Wednesday because a weekend intervenes. Line 2 shows time-value days forward, relative to the settlement date which is on Wednesday in week 3. Lines 3 and 4 show $n_t - n_{t-1}$, which is the sequence of time-value days in a series of spot and forward returns, r_s or r_f. Lines 5 and 6 show the time value days in a series of return differences and in a series of forward premiums p. The last column shows the standard deviation of the actual regressor, $n.R$, in percent *p.a.*, for a hypothetical stock that would have had no missing data.

regression error.[14]

One possible objection against the first and second test equation is that expected true returns should be higher, on average, in periods with high risk-free rates, which would introduce some correlation between noise and the regressor and, therefore, bias the slope coefficient upward if $\triangle n_f > 0$ and downward if $\triangle n_f < 0$. We provide an upper bound on this effect in the Appendix, where we conclude that the bias must be trivial.

A second issue is statistical power, with as its two prime determinants the variances of the regressor and of the regression error term. Most of the variability in the regressor, a time-value effect, stems from the ever-changing number of days to settlement. Table 4 shows how, over a two-week period, the days to delivery evolve in each market (lines 1-2) and it shows what the resulting time-to-settlement pattern is in spot and forward returns. Obviously, working with spot returns provides far less power than with forward returns where, for about the same error variance,[15] the regressor has a standard deviation that is about three times higher. But either method suffers from an extra source noise, as the regression error comprises not only the two

[14]Note, in passing, that because of the absence of market makers, every price is not a firm quote but a number that is the stochastic outcome of an auction or call. The usual arbitrage one sees in currency markets is not possible here because there are no firm quotes. The only type of arbitrage that can (and should) occur is when market orders are placed. Then the choice of the market should be based on the expected prices to be produced by the opening call.

[15]as far as we can judge from the preliminary tests.

pricing errors but also the common one-day true return.

In the next test equation, *i.e.* the difference-of-return equation (11), the regressor has an even better variability than the forward-return regression, as one can see in Table 4. If prices had been synchronous, there would have been no true return in the regression either. In reality, the timing difference means that there are two true morning return items in the residual, and whether this is better than one full-day return is far from obvious. Moreover, this difference-of-returns test involves four pricing errors instead of two besides the two true return terms, and it has more missing observations: we lose any day where either a spot or a forward price is missing, contemporaneous or lagged once. The last test equation (12) seems to have it both ways: only a half-day true return shows up in the error term, and the regressor has very good variability (see also Table 4). Consequently, the forward-premium test equation dominates the difference-of-returns version in that it involves just two price error terms plus one true morning return and it generates fewer missing data. In addition, times to maturity are well spread all over the spectrum in the former equation. For the regressions based on r_f or r_s, in contrast, there is a low-variability sample most of the time, interrupted by a big outlier at the change of the *quinzaine*, which provides a very influential subsample of just about 192 observations, about 10 percent of the total. Yet using forward premiums instead of returns is not the perfect solution either. Relative to the single-return-based regressions, the drawback is that it uses cross-market information, postulating that time value is taken into account to the same extent in the two markets. The spot- or forward-return-based tests obviously do not need that. Since no equation clearly dominates on all counts, we report results for both returns and forward premiums.

2.3 Aggregated Estimates

In testing for settlement effects (or for autocorrelation of forward premiums, for that matter) we first consider individual estimates. But we also want to look at aggregate or average results. For one, aggregate results provide summary measures on, for example, the settlement effect for the entire forward-spot Brussels Stock Exchange (the macro level) or for meaningful subgroups, like turnover-based portfolios.[16] An additional motivation for macro inference is that individual estimates are often noisy and imprecise. Therefore, the test results from aggregate data could support or complement the individual tests. For example, if most individual estimates are

[16]Thanks to Pierre Hillion for this suggestion.

significant, aggregate estimates are expected to be so too, but the aggregate can be significant even when most individual estimates are not. In this sense, we investigate a kind of average of the estimates.

One question that arises in this connection is the heterogeneity among the estimates of the individual series. According to Pesaran and Smith (1995), there are four procedures that can be used to estimate this average effect: the mean group estimator (estimating separate regressions for each group and averaging the coefficients over groups), pooled regression, aggregate time-series regressions, and cross-section regressions on group means. In the static case, where the regressors are strictly exogenous and the coefficients differ randomly and are distributed independently of the regressors across groups, all four procedures provide a consistent and unbiased estimate of the coefficient means (Zellner, 1969). The aggregate time-series regression procedure involves averaging data over groups into a portfolio. This procedure is not suitable for our data because too many observations are lost during the aggregation. Since, in each of the settlement-effect tests, the regressors are identical across stocks, the independence condition is obviously met. So, a panel data procedure for estimating the average effects is justified here. For time value estimation in our studies, the aggregation estimate in principle equals the average of the individual ones, since individual regressions have the same regressor.

2.4 Empirical Results on Settlement Effect Tests

We report the empirical results of the single return series tests and then of the forward premiums test in order to estimate whether the time value is correctly reflected in prices.

From Equations (9)-(12), the settlement effect is tested for by regressing the daily spot or forward returns, or the daily forward premiums, on the corresponding time value:

$$\mathrm{E}(r_{s,t+\tau}|\Delta(n_s R)_t) = \alpha_s + \beta_s \cdot \Delta(n_s R)_t, \tag{13}$$

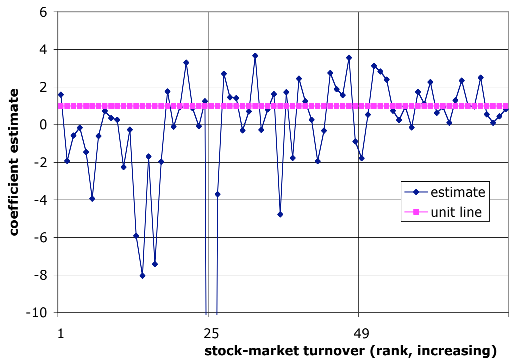
$$\mathrm{E}(r_{f,t}|\Delta(n_f R)_t) = \alpha_f + \beta_f \cdot \Delta(n_f R)_t, \tag{14}$$

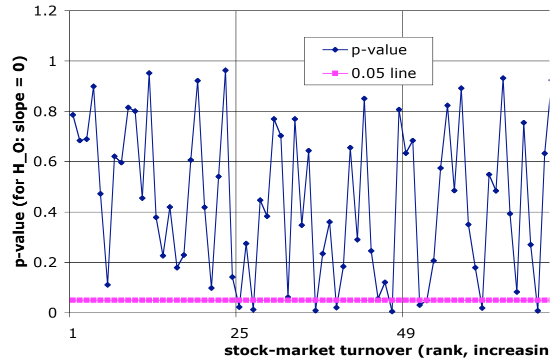
$$\mathrm{E}(p_t|\Delta(n_s^f R)_t) = \alpha_p + \beta_p \cdot \Delta(n_s^f R)_t. \tag{15}$$

We expect a slope of unity or, if there are tax effects (10% withholding tax), a number no lower than 0.9.

The general picture is one of positive coefficients but, typically, less than half of the estimates are above unity and the aggregate coefficients are below unity. There are some surprising differences across data types, though.

Figure 4: **Time Value Coefficient Estimates and p-Values, Spot Returns**





key: Returns (spot) for 72 stocks are regressed on the theoretical time-value effect, $\Delta(nR)_t$, and we expect a slope of unity or at least 0.90. The figures show the slope estimates (to the left) and their p-values (to the right). The stocks are ranked by turnover. Stock 25, whose coefficient falls outside the graph, has an outlier estimate of -66. Estimates per stock are plotted for stocks ranged by turnover rate. For visibility, the dots are linked by line segments, but any similarity to a time-series plot is unintended.

Table 5: **Time Value Effects in Returns and Forward Premiums: selected summary statistics in single-series tests**

	# of rejections of ...				# of coefficients > 1 in sample:			
						Turnover classes:		
regressee	$\beta = 0$	$\beta = 1$	both	neither	All	Low	Mid	High
spot return	9	4	2	61	26	4	12	10
forward return	14	38	3	23	13	9	1	3
forward premium	25	36	7	18	14	9	2	3

key: Returns (spot or forward) and *ex-post* forward premiums for 72 stocks are regressed on the theoretical time-value effect, $\Delta(nR)_t$, and we expect a slope of unity or at least 0.90. The table provides some summary statistics on the 72 slope estimates in each regression.

2.4.1 Spot returns

We start by outlining the findings. At the individual level, the settlement-effect test suggests that the time value is usually not correctly taken into account in the spot prices and the estimation uncertainties are huge. At the macro level, *i.e.* the aggregate regression, the panel-data estimates show that the time value seems to be correctly reflected in the spot prices in the group of high-turnover stocks, but probably not in the mid-turnover group and definitely not among the thinly-traded stocks. However, also because of low variation in the regressor, the estimates are very imprecise in the total group and the three subgroups. Actually, even the total absence of any attention to time-value factors is statistically acceptable for the groups of low- and medium-turnover stocks.

Table 6: **Time Value Effects in Returns and Forward Premiums: Aggregates**

sample (by turnover)	single time-series $\hat\beta$ avge	median	$n_{>1}$	panel estimation of $\hat\beta$: $\hat\beta$	SE($\hat\beta$)	t-stat	prob	Wald Test - Null: Slope=1: F-stat	d.o.f.	prob
spot returns: $E(r_{s+\tau} \mid (\Delta(n_s R)_t) = \alpha + \beta \cdot \Delta(n_s R)_t$										
All	-0.72	0.67	26	0.44	0.67	0.66	0.5113	0.68	(1, 95589)	0.4093
Low turnover	-1.06	-0.22	4	-0.68	0.74	-0.92	0.3584	5.16	(1, 27574)	0.0231
Medium	-2.16	1.03	12	0.56	0.71	0.79	0.4275	0.38	(1, 31167)	0.5363
High	1.07	0.94	10	1.19	0.77	1.55	0.1223	0.06	(1, 36846)	0.8077
forward returns: $E(r_f \mid (\Delta(n_f R)_t) = \alpha + \beta \cdot \Delta(n_f R)_t$										
All	0.55	0.27	13	0.29	0.16	1.81	0.0702	19.64	(1, 87549)	0.0000
Low turnover	1.01	0.56	9	0.47	0.22	2.14	0.0320	6.05	(1, 21684)	0.0139
Medium	0.17	0.14	1	0.23	0.18	1.27	0.2042	18.81	(1, 29195)	0.0000
High	0.45	0.23	3	0.24	0.19	1.27	0.2034	16.94	(1, 36668)	0.0000
forward premiums: $E(\ln(F/S)_t \mid (\Delta(n_s^f R)_t) = \alpha + \beta \cdot \Delta(n_s^f R)_t$										
All	0.44	0.29	14	0.41	0.09	4.74	0.0000	44.79	(1, 76670)	0.0000
Low turnover	0.85	0.66	9	0.56	0.16	3.54	0.0004	7.87	(1, 18009)	0.0050
Medium	0.15	0.36	2	0.43	0.10	4.16	0.0000	31.58	(1, 25829)	0.0000
High	0.33	0.21	3	0.33	0.10	3.19	0.0014	41.89	(1, 32830)	0.0000

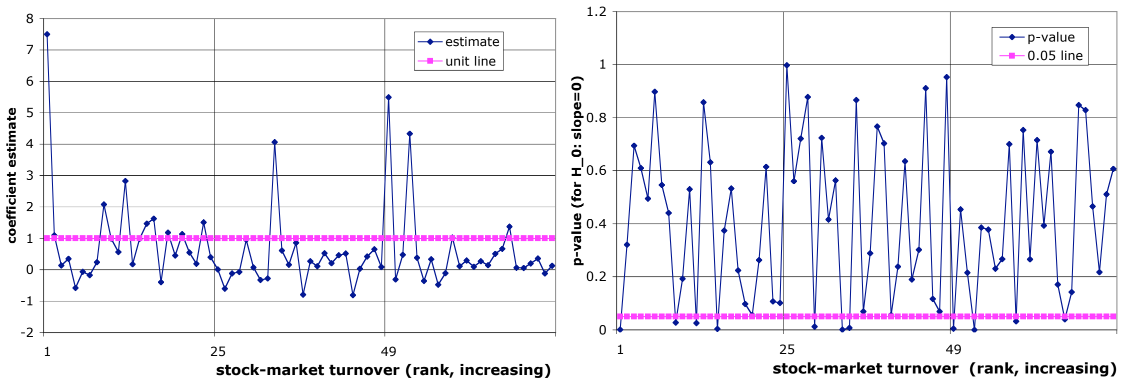
Key: Returns (spot or forward) and *ex-post* forward premiums for 72 stocks are regressed on the theoretical time-value effect, $\Delta(nR)_t$. We do this for the entire sample (72 stocks), and then for three subsamples ('low', 'medium', 'high') of stocks arranged by average daily turnover.

Here are the details that support the above claims. The results for the equation-by-equation tests in the spot market are summarized in Figure 4 and in the leftmost and top panels of Tables 5 and 6. Some of the news is quite good. Out of 72 coefficients, 26 exceed unity; in the mid- and high-turnover samples the figures are even 12/24 and 10/24, and the medians for these groups are very close to unity. But all this is overlaid by a pattern of very noisy estimates that exhibit a big negative skewness. Stock 25, in the mid-turnover group, achieves an incomprehensible estimate of –66, producing a sub-sample mean of –2.16 against a median of 1.03. Only for the high-turnover group, skewness does not seem to be a problem. Imprecision is huge. No less than 61 stocks out of 72 accept both a zero and a unit value for the coefficient.[17] Only nine reject a zero value, and four reject a unit value; of these, two reject both.

The imprecision problem is our prime motivation for adding aggregate estimates. With regard to the macro inference, the panel data estimates in the middle columns in Table 6 show that aggregates turn out to give less weight to the negative individual estimates, meaning that these were deemed to be very noisy. The resulting estimates are, roughly speaking, between

[17] All significance statements in this paper are at the 5% level, one-sided.

Figure 5: **Time Value Coefficient Estimates and p-Values, Forward Returns**



Key: Returns (forward) for 72 stocks are regressed on the theoretical time-value effect, $\Delta(nR)_t$, and we expect a slope of unity or at least 0.90. The figures show the slope estimates and their p-values. The stocks are ranked by turnover. Estimates per stock are plotted for stocks ranged by turnover rate. For visibility, the dots are linked by line segments but any similarity to a time-series plot is unintended.

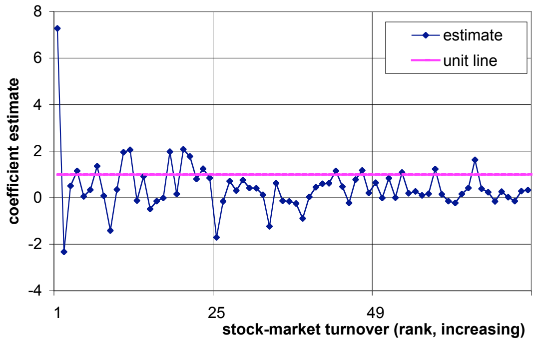
the unweighted means and the medians. The time value coefficient is insignificantly positive in the pooled sample of all 72 stocks and all three subsamples. Except for the the low-turnover group, the coefficient estimate is, in addition, not significantly different from unity. As for the other two groups, the time value has no statistically significant impact on returns and, for the low-turnover stocks, its slope coefficient is definitely not equal to unity either. We conclude that, generally, and with the notable exception of most active stocks, the time value effect was not taken into account in the spot prices.

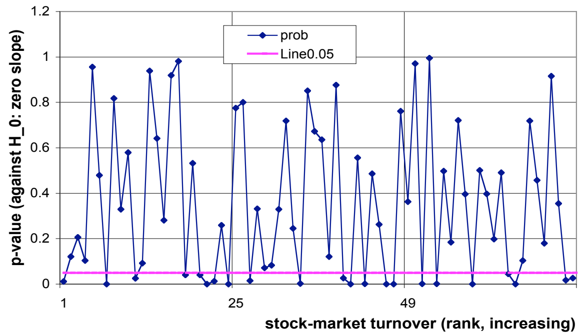
2.4.2 Forward Returns and Forward Premiums

The results for forward premiums and forward returns are similar. Also in these data the general picture is one of coefficients that are positive but below unity, as we substantiate below. An expected finding is that precision is up, especially for forward premiums. Unexpectedly, however, relative to results from spot returns, medians and general averages are generally lower except for low turnover stocks (which, admittedly, did very badly in the spot-return-based tests). Medium turnovers and especially the active stocks do worse in this test than low turnover stocks. Lastly, there is right-skewness rather than left-skewness. Let us consider the evidence behind these claims.

Out of the total 72 stocks, the number of series that accept both a unit and a zero slope value falls from 61 (r_s) to 23 (r_f) and 18 (p). The number of stocks that reject both a zero and a unit slope rises from 2 to 3 or 7. All this suggests better precision, as expected given the

Figure 6: **Time Value Coefficient Estimates and p-Values, Forward premiums**





Key: Realized forward premiums for 72 stocks are regressed on the theoretical time-value effect, $\Delta(nR)_t$, and we expect a slope of unity or at least 0.90. The figures show the slope estimates and their p-values. The stocks are ranked by turnover. Estimates per stock are plotted for stocks ranged by turnover rate. For visibility, the dots are linked by line segments but any similarity to a time-series plot is unintended.

clearer signals.

More precision should mean more significantly non-zero results, everything else being the same. The number of rejections of a zero slope rises from 9 to 14 (r_f) or even 25 (p). One would expect these clearer signals also to be reflected in prices to a larger extent than the feeble signals that are present in spot markets, *i.e.*, also coefficients should rise. Yet this turns out to be too optimistic. Most of the estimates are positive indeed, but the number of slopes above unity has shrunk from 26 (spot returns) to 13 (forward returns) or 14 (premiums). Relatedly, more stocks—38 or 36, up from 4—now reject a unit slope. Average and median slopes are down in all samples except for the low-volume group. Curiously, in light of the spot-return results and intuition, low-turnover stocks actually do best now: most above-unity slopes now are low-turnover stocks (9/13 for r_f, 9/14 for p instead of 4/26 for r_s). This is also reflected in the averages and medians of the single-series estimates: these look impressively close to unity for low-turnover stocks and then fall if we go higher on the turnover scale.

As for the macro analysis, the panel data estimation in Table 6 shows that, except for the mid- and high-turnover groups in the forward return test, time value is definitely a factor in all the remaining six cases: each of the six coefficient estimates is significantly positive. Yet, they now also all reject a unit slope statistically, and even the best numbers are further below unity than what we saw in spot data. Third, again confirming the results from individual regressions and contrasting with the findings from spot data, the highest aggregate coefficient is for the low-turnover group, with the lowest for the medium- (r_f) or the high-turnover stocks (p).

To sum up: in the spot market we actually see very little evidence in favor of or against a time-value effect. In the forward markets, where the time value signals should be stronger, we do find that the time value affects prices, but the effect remains substantially smaller than what theory predicts. As expected, the estimate from the forward premiums provides the cleanest results, but, even there, the estimates remain below our theoretical priors. In the next section, we question the hypothesis of market efficiency under which the forward premiums should be unpredictable.

3 Autocorrelation in the Price Discrepancies

Let us define the settlement-corrected forward price and premium as follows:

$$F'_t := F_t \frac{1 + n_{s,t} R_t}{1 + n_{f,t} R_t}, \tag{16}$$

$$p'_t := ln \frac{F'_t}{S_{t+\tau}}, \tag{17}$$

$$= -\rho^m_{t+1} + e_{f,t} - e_{s,t}. \tag{18}$$

As of now, the prime refers to the time-value-corrected version, p'.

In our proposed model for the efficient markets, we assume that the true return ρ and the noises ϵs are unpredictable. This hypothesis means that the the premium p' should have zero autocorrelation. We will now examine the autocorrelation of the forward premium.

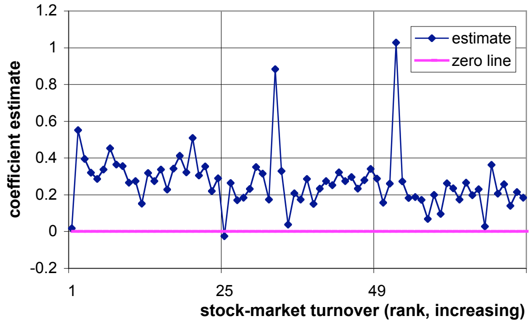
3.1 Autocorrelations in Forward Premiums

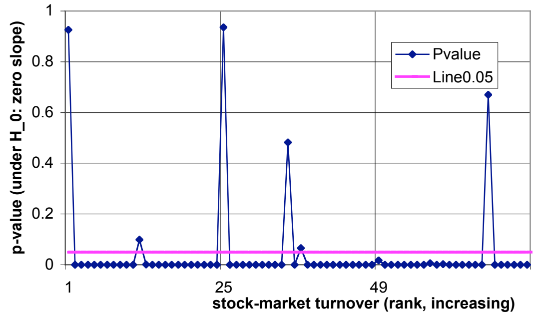
Figure 7 summarizes the autocorrelation of the forward premium for the individual stock estimates visually, while Table 7 provides some numerical information. The obvious feature is that autocorrelation is positive. Out of the total 72 cases, only one estimate actually is negative, and only marginally so, while 66 cases or 91.7% of the estimates are significantly positive. The averages and the number of significant rejections tend to fall the more active the stock is, but the effect is quite slight: the general average coefficient is 0.27, falling from 0.32 to 0.24 as we go from thinly to actively-traded stocks. The medians are similar.

For aggregates obtained via panel regression, we test the independence assumption by regressing, for every equation, the 72 slopes on the corresponding turnovers. For the sample as a whole there is, unsurprisingly, a significant negative relation, but within turnover groups

Figure 7: **Autocorrelation in the Forward Premiums, Stock by Stock.**

$$\mathrm{E}_{t-\Delta}\left(\frac{F'_t - S_t}{S_{t-1}}|S_{t-1}, F'_{t-1}\right) = \gamma_0 + \gamma_1 \frac{F'_{t-1} - S_{t-1}}{S_{t-1}}$$





Key: *ex-post* forward premiums for 72 stocks are regressed on their lagged value. This slope, γ_1, estimates the scaled autocovariance of the forward premiums. A zero γ_1 means that the forward premiums are not correlated, a positive one signals positive autocorrelation in premiums, meaning that the true-morning-return is also autocorrelated of first-order. We show estimated gammas and their p-values for all stocks, arranged by daily average turnover. Estimates per stock are plotted for stocks ranged by turnover rate. For visibility, the dots are linked by line segments but any similarity to a time-series plot is unintended.

Table 7: **Test of Autocorrelation in the Forward Premiums.**

$$\mathrm{E}_{t-\Delta}\left(\frac{F'_t - S_t}{S_{t-1}}|S_{t-1}, F'_{t-1}\right) = \gamma_0 + \gamma_1 \frac{F'_{t+1} - S_{t-1}}{S_{t-1}}$$

sample	individual series estimation					panel estimation			
(by turnover)	mean	median	$n_{>0}$	sgnf$_{>0}$	sgnf$_{<0}$	$\hat{\gamma}_1$	SE(.)	t-stat	prob
All	0.27	0.26	71	68	0	0.29	0.011	25.33	0.0000
Low turnover	0.32	0.32	24	23	0	0.32	0.022	14.30	0.0000
Medium	0.26	0.26	23	22	0	0.27	0.016	17.08	0.0000
High	0.24	0.20	24	23	0	0.26	0.012	21.50	0.0000

Key: *ex-post* forward premiums for 72 stocks are regressed on their lagged value. A zero γ means that the forward premiums are not correlated, a positive one signals positive autocorrelation in premiums, meaning positive autocorrelation in the true-morning return. We show summary statistics for all stocks and for three subsamples of stocks arranged by daily average turnover.

there is no more clear link (Table 8). The aggregates are very similar to the straightforward means of individual estimates, and are clearly different from zero. All this implies that the forward premium is predictable, which is a sign of inefficiency—for example, a differentially slow dissemination of the fundamental information for at least one day.[18] This phenomenon occurs across the entire spectrum of trading volume. So, the question is whether this is, economically, an anomaly or not.

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[18] Autocorrelation in the true morning returns could be a source of autocorrelation in price discrepancies, but it is almost unthinkable, in an efficient market, that the true returns could generate daily autocorrelation of 0.3. Also, we see no such high autocorrelation in either spot or forward returns.

Table 8: **Preparing for Panel Estimation: Independence Tests for Slopes**

	regressing γ_j on turnover		
	slope	t-stat	prob
All	-1.80	-2.63	0.0104
Low turnover	2.96	0.10	0.9199
Medium	12.35	1.90	0.0707
High	-0.37	-0.40	0.6943

Key: γ_1 estimates the scaled autocovariance of forward premiums. To be able to estimate the mean gamma via panel regressions with a common slope we need to test that individual stocks' gammas are deviating randomly from a general mean. Here we test whether there is a relation with turnover, first in the all-stock sample and then in the three subsamples of stocks assembled on the basis of average daily turnover.

We first ask whether the predictability is so large as to allow profitable two-way arbitrage (buying low, selling high), and find that it is not.[19] We also find that the persistence may have to do something with a cash-is-king effect: there is an inconvenience in finding cash (think of the hassle, the delays), so buyers prefer to buy forward and sellers prefer to sell spot.

3.2 Trading Strategy

In the preceding section, we saw that the autocorrelation of the forward premium is significantly positive, implying a partial predictability of next-day price discrepancies. In this section, we will test whether it is possible to exploit this result, that is, whether we would make money if, whenever the forward is too high relative to the spot price, we place market orders for a spot purchase and a forward sale at the next opening, and *vv.* We will also test whether the payoff from this 'arb' strategy is significantly higher/lower than that from similar trades where stocks are selected randomly rather than on the basis of an earlier price imbalance.

We study six trading rules. The three 'buy spot/sell forward' rules are triggered by an abnormal premium between 2 and 3%, between 3 and 4%, and above 4% respectively, while the three 'sell spot/buy forward' rules react to abnormal premiums between –2 and –3%, between –3 and –4%, and below –4% respectively. Below, we will describe in detail one strategy based on the positive-2-percent event. The other five strategies are similar.

[19] For two-way arbitrageurs, as defined by Deardorff (1979), the discrepancy should exceed the two-way transaction cost. One-way arbitrageurs, in contrast, are liquidity traders or information traders who just choose in which market they buy or sell. Such traders weigh the cross-market price discrepancy against the difference of the transaction costs instead of their sum, so transaction costs play almost no role for one-way arbitrageurs.

Every day, each of the 72 stocks is evaluated for eligibility to be traded on the next day. Consider the trading strategy based on a +2-to-3% event. If the event occurs for a stock j on day t, we expect that at the next opening its forward price will still be too high, relative to the spot. So we immediately sell high/buy low: we place market orders for execution the next day to sell stock j forward and buy it back spot. If the long position is funded by borrowing money, this is a zero-investment strategy. The payoff is realized at the end of the *quinzaine*, when the forward trade is settled and the loan for the stock trade paid back. Yet, note that this payoff is fully known as soon as the spot market has opened.

Obviously, there are likely to be days with more than one such trade per day. So we want to study the payoff for a portfolio with a daily varying number of positions. We consider two versions. In the first and most straightforward one, the daily credit line is fixed at BEF 10 million, to be divided equally across the number of stocks selected, denoted as n_t. The payoff after transaction costs is computed using the transaction cost calculated from Table 2 for n_t orders worth $10\text{m}/n_t$ each. On each forward settlement date, we add up our total proceeds across the stocks per day of trading and then across all trading days inside the expiring settlement period. We report the number of positive outcomes as well as the number of significantly positive and negative outcomes. To get these significance bounds we proceed via a bootstrap described below.

The drawback of this fixed-portfolio-size rule is that the riskiness of the payoff varies substantially over time, in line with n_t. In the alternative application, we abandon the fixed size and go for an approximately constant risk instead. Specifically, the daily portfolio size is set at BEF $10\text{m}\times\sqrt{n_t}$. Again, this daily credit line is allocated equally across the n_t stocks, which makes each order size for each stock equal to BEF $10\text{m}/\sqrt{(n_t)}$. The advantage is that the problem of a changing standard deviation of the portfolio, following from day-to-day changes in n_t, is much reduced. In fact, if all trades were equally risky and mutually independent, the portfolio variance would be constant:

$$\text{for IID } \tilde{x}_j\text{: var}\left(\frac{1}{\sqrt{n}}\sum_{j=1}^{n}\tilde{x}_j\right) = \frac{1}{n}\sum_{j=1}^{n}\text{var}(\tilde{x}_j) = \text{var}(\tilde{x}).$$

In a less heteroscedastic time series of net gains per quinzaine we expect our test to have greater statistical power.

A trading strategy based on a negative event is similar, except of course that if a negative event occurs for a given stock, we will sell that stock forward and buy spot on the next day, as we expect that the negative premium should still be there to some extent. We also implement the trading rule with subgroups of stocks, for instance, considering only the 24 low-turnover stocks rather than the full set of 72. The number of settlement periods for which there was at least one trade varies, depending on the sample.

The risk of these strategies derives from two sources: there is three and a half hours of 'true' returns (from 10 a.m. and 1.30 p.m.), and there is microstructure noise. This matters for two reasons. First, even under the null of no predictability, buying at 10 a.m. and selling at 1:30 p.m. should still earn a positive expected return; thus, although it is of interest to know how often this is profitable, the relevant null is not that the expected payoff is zero. Absent a non-controversial model of normal returns, we therefore compare the payoff with the distribution of bootstrap payoffs which, under the null of no predictability, should have similar expected returns. A second reason why the risk structure of such an arb trade matters is that its payoff is hard to annualize. Note indeed that, in perfect markets without predictability, this risk would be identical whether we place the orders one day beforehand, or one week, or one month. Therefore, even though we trade every working day, the returns are not really one-day returns in the usual sense: under the null, the expected payoff and risk of one arb order with daily trading is the same as with weekly or monthly trading. In short, the usual rule of annualization ($\times 250$ for means and variances) does not really apply here.[20] So we abandon the usual Sharpe ratio as our measure of success. Instead, we again resort to the bootstrap.

In this bootstrap, we test whether the payoff from these strategies is significantly different from the results obtained by a large control group of hypothetical traders who, every day, place exactly the same number of orders (n_t) as we do, except that they pick the stocks randomly. Therefore, we design our bootstrap procedure as follows. On each day, we randomly select n_t stocks from the total list of 72 and build equally weighted portfolios of size $10m$ or $10m\sqrt{n_t}$. We repeat this step 1000 times to have payoffs from a control group of 1000 random traders for each settlement date. We lastly check, for each and every settlement period, whether or not the payoff from our trading strategy is outside the period's 5%-95% percentile payoffs, $P_{0.05}$ and $P_{0.95}$, obtained by the control group. If it is above the 95% bound, we say that our strategy's payoff for that date was significantly higher than that of the random trades. We do this comparison not only for before-cost payoffs but also for after-cost payoffs.

[20]One could argue that the information-related risk bears on 3.5 hours, but how this is to be annualized is not easy to say, as it depends on morning v afternoon v overnight v weekend risk, etc. And even if we knew how many 'morning-equivalents' there are in a year, informationwise, the annual microstructural noise would still

Table 9: **Mean and Median of the Returns (percentage)**

	+ 2-3		+ 3-4		>+4		− 2-3		− 3-4		<−4	
number of events	4099		1485		1309		1685		593		500	
number of trades	3709		1294		1058		1554		545		480	
	Payoff of strategies with the daily portfolio size of BEF 10 million; %/*quinzaine*											
	gross	net	gross	net	gross	net	gross	net	gross	net	gross	net
mean	1.08	-1.41	1.43	-0.65	1.73	-0.32	0.44	-1.73	0.61	-1.36	0.72	-1.28
median	1.13	-1.42	1.47	-0.66	1.66	-0.39	0.46	-1.79	0.68	-1.35	0.78	-1.15
	Strategies with the daily portfolio size of BEF 10 million$\times\sqrt{n_t}$											
mean	1.08	-0.61	1.97	0.17	1.94	0.07	0.43	-1.34	0.45	-1.48	0.36	-1.55
median	1.13	-0.56	1.84	0.03	1.73	-0.13	0.45	-1.34	0.34	-1.81	0.28	-1.73

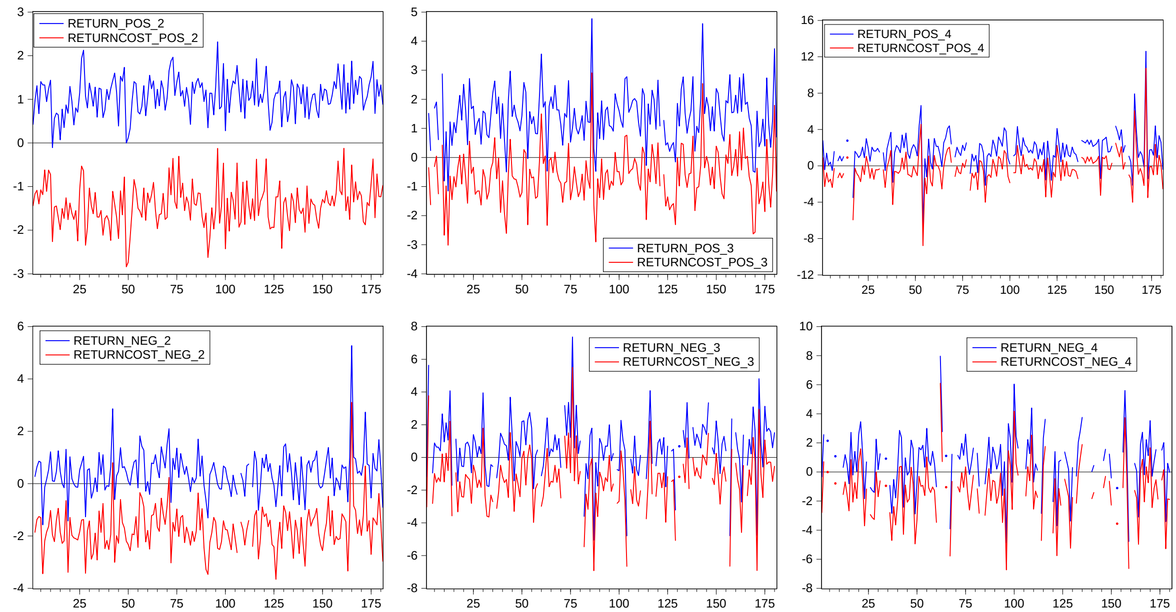
Key: This table reports the mean and median of the returns and the after-cost returns of the zero-investment trading strategies, each of which is based on one of the six events, accumulated at every settlement date. pos_2, pos_3, and pos_4 are for the positive event of 2%, 3%, and 4% respectively; neg_2, neg_3, and neg_4 for the negative event of 2%, 3%, and 4% respectively. In these trades, the daily portfolio size is either BEF 10 million or BEF 10 million multiplied by the square root of n_t, which is the number of stocks selected for trading

For the hasty reader, Table 9 and Figure 8 provide the key information on the magnitude of the payoffs relative to the notional investment. The tables show mean and median returns, in percent per *quinzaine*, before and after costs. These after-cost typical payoffs are negative in 10 (11) cases out of 12, if one considers just the means (medians). The exceptions occur for the variable-size portfolio, if one reacts only to larger positive signals (> 3%); and even these gains are trivial (the means are 0.17 and 0.07% per *quinzaine* of trading; the medians are even worse). These mean and median numbers provide no information on risk, but the visual material does give a first insight. In each of the graphs, the upper time-series plot shows before-cost payoffs, the lower one the net results after costs. There is one such graph for each of the six trading rules, so we have a set of six pictures for the fixed-budget trader (BEF 10m) and another for the variable-budget one. We see that even for the two rules that looked marginally promising in terms of means there is substantial risk. Notably, even in the second and third graph of Figure 8, the lower plot dips below the zero line about one *quinzaine* out of two, and occasionally quite spectacularly so. In short, the picture is not hardly one of nearly

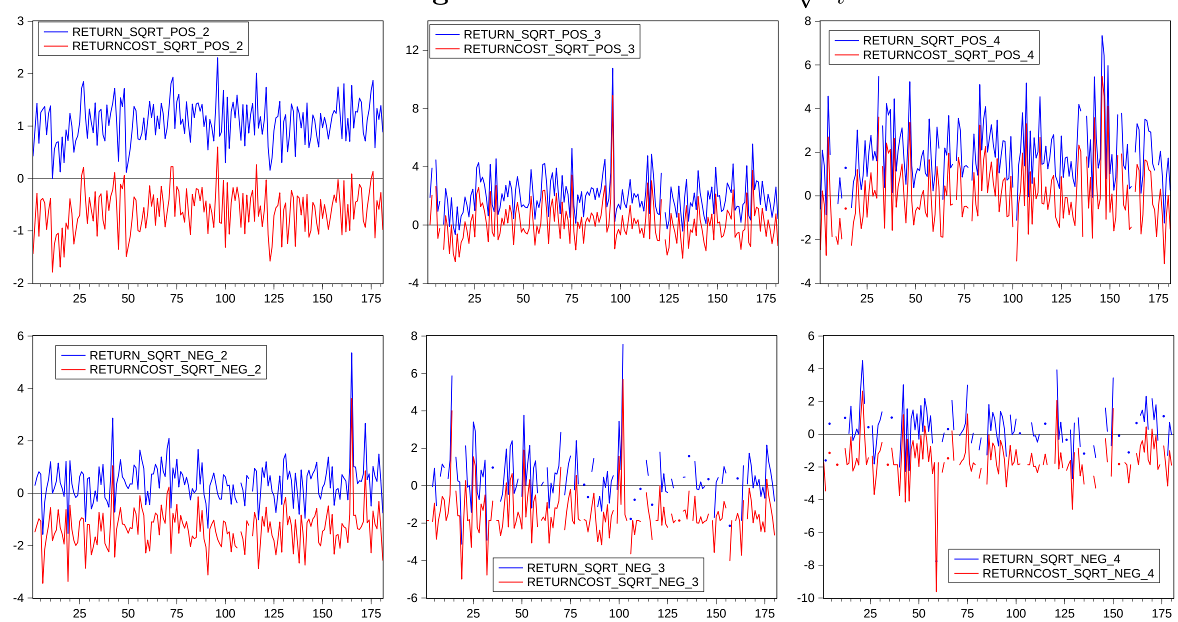
be horizon-independent. That is, we would need to know each of the three components of the 10 a.m.-to-1:30 p.m. variance.

Figure 8: **Returns on the zero-investment trades (percentage)**

Trading limit fixed at BEF 10m



Trading limit set at BEF 10m$\times\sqrt{n_t}$



Key: These graphs report the returns and after-cost returns of the zero-investment trading strategies, each of which bases on one of the six events, accumulated at every settlement date. In these trades, the daily trading limit for one leg is BEF 10m (top six graphs) or, for the lower six graphs, BEF 10m $\times\sqrt{n_t}$, where n_t is the number of stocks selected for trading. The vertical axis shows the percentage returns, and the horizontal axis is for the 181 settlement dates.

risk-free arbitrage. We now take a closer look at these results, including the numbers for the subgroups of stocks per turnover class and the results for the control group, the bootstrap.

Tables 10 and 11 report summary statistics for the payoffs of the six strategies and the bootstrap. We start discussion with the gross (*i.e.* pre-cost) numbers for the +2% rule in Table 10. The accumulated payoffs at each of the settlement dates are overwhelmingly often positive (in 179/181 periods)—but so are the majority of the outcomes in the control group, the bootstrap experiment: in 100 *quinzaine*s, even the 5% unluckiest Monte-Carlo trader still manages to stay out of the red zone. If, instead, we focus on how often the trading rule does significantly better than our dice-tossing control groups, we see clearly unusal profits in a less impressive 31 *quinzaines*, *ie* one out of six. The higher the initial forward premium we require before we trade, the more pronounced the gains, both algebraically (Table 9) and statistically (Table 10): the number of outcomes exceeding the period's $P_{0.95}$ value rises from 31 to 37 and even 71 out of about 180 periods if we increase the hurdle to +3 or +4%. The impact of volume on significance seems to be fuzzy: high-volume stocks are clearly profitable more often than low-turnover stocks if one looks at the +2% rule, but that pattern seems to be obscured by the lower degree of diversication resulting from fewer trading signals when the hurdle is set at 3 or 4%.

The results from the negative-event-related strategies are somewhat more mixed. First, roughly one *quinzaine* out of three ends in the red even before costs. This could be due to the systematic short positions between 10 a.m. and 1:30 p.m. we already know that selling forward at 9 a.m. and closing out at 1:30 p.m. (the long version of what we do now) was quite profitable. A second result is that the number of conspicuously good periods relative to the control group (*i.e.* with outcomes $> P_{0.95}$) is much smaller than what we see for positive premiums: 19 (versus 31) for –2% (v +2%), 34 v 37 for ±3%, and even 39 v 71 for ±4%. Simultaneously, the number of unusually bad results becomes quite large: in the 72-stock applications, for instance, there are already more signal failures than signal successes in the –2% case, and the number of significantly bad outcomes stays at 15% for the –3 and –4% rules. This is, of course, not due to shorting: in the control group, the hypothetical traders are short too. Rather, our trading rule is betting on continuation, so losses stem from unexpected reversals; and since we observe losses anomalously often, we can infer there were an anomalously large number of such reversals. Thus, the results tell us that, given an initial negative premium, the process is more like a 'switch' AR(1) than a regular one: often, negative premiums still tend to be

Table 10: **Bootstrap Significance Test of the Payoff: fixed trading limit**

	payoff		$P_{0.05}$	$P_{0.95}$	payoff		payoff $< P_{0.05}$		payoff $> P_{0.95}$	
	>0	<0	>0	<0	$< P_{0.05}$	$> P_{0.95}$	and >0	and <0	and >0	and <0
	Trading strategy corresponds to the positive event of 2-3%									
All	179	2	100	0	9	31	9	0	31	0
Low	176	4	81	0	6	34	6	0	34	0
Medium	160	19	30	0	4	29	2	2	29	0
High	137	32	24	0	9	39	1	8	39	0
All, after cost	**0**	**181**	**0**	**154**	**9**	**31**	**0**	**9**	**0**	**31**
	Trading strategy corresponds to the positive event of 3-4%									
All	167	10	41	0	2	37	1	1	37	0
Low	160	12	30	0	1	30	0	1	30	0
Medium	124	20	5	0	1	25	0	1	25	0
High	89	22	7	0	4	13	0	4	13	0
All, after cost	**36**	**141**	**0**	**96**	**2**	**37**	**0**	**2**	**18**	**19**
	Trading strategy corresponds to the positive event of > 4%									
All	151	19	24	0	8	71	0	8	71	0
Low	133	15	18	0	1	62	0	1	62	0
Medium	98	28	3	0	7	25	0	7	25	0
High	48	16	1	2	3	9	0	3	9	0
All, after cost	**64**	**106**	**0**	**103**	**8**	**71**	**0**	**8**	**51**	**20**
	Trading strategy corresponds to the negative event of –2-3%									
All	127	51	13	0	22	19	0	22	19	0
Low	95	67	4	0	37	14	0	37	14	0
Medium	118	41	3	1	14	38	0	14	38	0
High	93	57	3	0	26	35	1	25	35	0
All, after cost	**4**	**174**	**0**	**145**	**22**	**19**	**0**	**22**	**4**	**15**
	Trading strategy corresponds to the negative event of –3-4%									
All	113	48	1	0	24	34	0	24	34	0
Low	69	37	2	0	21	14	0	21	14	0
Medium	95	34	1	0	16	33	0	16	33	0
High	34	27	2	0	11	14	0	11	14	0
All, after cost	**25**	**136**	**0**	**82**	**24**	**34**	**0**	**24**	**20**	**14**
	Trading strategy corresponds to the negative event of $< -4\%$									
All	97	38	2	0	21	39	0	21	39	0
Low	59	22	1	0	16	16	0	16	16	0
Medium	71	28	2	0	15	32	0	15	32	0
High	21	20	0	0	9	8	0	9	8	0
All, after cost	**29**	**107**	**0**	**81**	**21**	**39**	**0**	**21**	**27**	**12**

Key: We buy spot and sell forward after observing a forward premium that is positive and has the right size (see subheaders), and we buy forward and sell spot when the forward premium was negative and has the right size. Each daily portfolio is equally weighted and its overall notional size is BEF 10m; thus, if two arb trades are done on day t, each is a spot-forward swap for a 5m notional. This table reports the number of *quinzaines*, out of at most 181, (i-ii) that had a positive *cq* negative payoff; (iii) for which the 5%-percentile payoff $P_{0.05}$ was positive; (iv) for which the 95%-percentile $P_{0.95}$ was negative; (v-vi) the actual payoff was significant (below $P_{0.05}$ *cq* above $P_{0.95}$); (vii-viii) the payoff was unusually low and positive *cq* negative; and (ix-x) the actual payoff was unusually high and positive *cq* negative.

Table 11: **Bootstrap Significance Test of the Payoff: n_t-dependent trading limit**

	payoff >0	payoff <0	$P_{0.05}$ >0	$P_{0.95}$ <0	payoff $< P_{0.05}$	payoff $> P_{0.95}$	payoff $< P_{0.05}$ and >0	payoff $< P_{0.05}$ and <0	payoff $> P_{0.95}$ and >0	payoff $> P_{0.95}$ and <0
Trading strategy corresponds to the positive event of 2-3%										
All	180	1	108	0	7	39	7	0	39	0
Low	177	3	85	0	4	35	4	0	35	0
Medium	157	22	33	0	3	30	1	2	30	0
High	139	30	27	0	8	40	2	6	40	0
All, after cost	**10**	**171**	**2**	**112**	**7**	**39**	**1**	**6**	**3**	**36**
Trading strategy corresponds to the positive event of 3-4%										
All	171	6	44	0	1	81	1	0	81	0
Low	139	10	28	0	4	19	4	0	19	0
Medium	74	23	4	0	1	14	0	1	14	0
High	64	11	6	0	3	13	0	3	13	0
All, after cost	**90**	**87**	**2**	**76**	**1**	**81**	**0**	**1**	**68**	**13**
Trading strategy corresponds to the positive event of $> 4\%$										
All	155	10	24	0	1	75	0	1	75	0
Low	113	9	20	0	1	18	1	0	18	0
Medium	58	20	3	0	2	12	0	2	12	0
High	39	9	1	2	1	11	0	1	10	1
All, after cost	**76**	**94**	**0**	**87**	**1**	**75**	**0**	**1**	**64**	**11**
Trading strategy corresponds to the negative event of –2-3%										
All	133	45	12	0	23	20	1	22	20	0
Low	95	67	6	0	37	12	1	36	12	0
Medium	118	41	3	1	15	40	0	15	40	0
High	93	57	3	1	29	36	2	27	36	0
All, after cost	**4**	**174**	**0**	**133**	**23**	**20**	**0**	**23**	**3**	**17**
Trading strategy corresponds to the negative event of –3-4%										
All	79	48	1	0	17	19	0	17	19	0
Low	28	12	0	0	6	2	0	6	2	0
Medium	32	16	1	0	5	4	0	5	4	0
High	22	8	1	0	4	10	0	4	10	0
All, after cost	**14**	**147**	**0**	**75**	**17**	**19**	**0**	**17**	**12**	**7**
Trading strategy corresponds to the negative event of $< -4\%$										
All	68	40	1	0	9	14	0	9	14	0
Low	17	18	1	0	7	0	0	7	0	0
Medium	29	14	1	0	4	8	0	4	8	0
High	7	8	0	0	2	3	0	2	3	0
All, after cost	**11**	**125**	**0**	**74**	**10**	**14**	**0**	**10**	**8**	**6**

Key: We buy spot and sell forward after observing a forward premium that is positive and has the right size (see subheaders), and we buy forward and sell spot when the forward premium was negative and has the right size. Each daily portfolio is equally weighted and its overall notional size is BEF 10m$\sqrt{n}$. Therefore, if two arb trades are done on day t, each is a spot-forward swap for a 7.07m notional. This table reports the number of *quinzaines*, out of at most 181, (i-ii) that had a positive *cq* negative payoff; (iii) for which the 5%-percentile payoff $P_{0.05}$ was positive; (iv) for which the 95%-percentile $P_{0.95}$ was negative; (v-vi) the actual payoff was significant (below $P_{0.05}$ *cq* above $P_{0.95}$); (vii-viii) the payoff was unusually low and positive *cq* negative; and (ix-x) the actual payoff was unusually high and positive *cq* negative.

followed by negative premiums (hence the many significantly positive profits from betting on continuation), but there also is a sizeable chance that negative premiums will switch straight to positive ones (hence the many significantly negative outcomes). We will return to a possible economic interpretation in the next subsection.

When taking into account the trading cost, the after-cost payoffs become negative in most of the periods, as already noted w.r.t. the means. This holds for both positive and especially negative signals. The stronger positive signals (+3, +4%) are unprofitable less often, again in line with what we saw from the mean returns. Stronger negative signals are rarer, so more often there is no trading at all; but even after taking this into account, we see that negative outcomes are less rare too. Still, they remain by far the more likely outcome.

All of the above was for the fixed-size portfolio, set at BEF 10m. With the variable trading limit $10m\sqrt{n_t}$ we have a statistically better behaved time series of payoffs. This provides higher power in the sense of more significant results. For the positive signals, the improvement is marginal for the +2%/all-stock sample, but it strengthens with higher required signals and smaller samples. For example, for a +4% signal and all stocks, 75 payoffs get an 'excellent' rating relative to the control group, compared to just 71 with the fixed-limit portfolio; in an extreme example, in the +3% rule we do unambiguously well 81 times, against just 37 times with the fixed-limit portfolio. Consistently with the lower variance, also the results after transaction costs are negative less often. If one confines oneself to the bigger +-signals, we see what we already knew from the time series plots: the odds of winning become less uneven. Still, we never get better than a 50/50 gamble, after cost. Also for negative signals there is also more significance, but often in the wrong direction. In line with the switch-like patterns we already noted after negative signals, a more orderly statistical now means that the unexpected reversals become more visible; for the –2% signals, significantly good and bad outcomes are roughly in balance, and for the –3 and –4% cases the significantly bad outcomes dominate the good ones.

We conclude, first, that the 'arbitrage' transactions suggested by continuation of price discrepancies are never low-risk in nature, and usually even produce a negative modal result. That is, there seems to be no money conspicuously left in the table. This conclusion is conservative for two reasons. First, the above tests have assumed away one additional risk that real-world traders surely face: having traded at 10 a.m. in the hope of closing out at 1:30 p.m., they might find that the spot market is too far out of equilibrium, meaning that planned noon trades must be postponed for at least one day. This risk was assumed away by looking only at days where both markets trade, *ex-post*. On other low-liquidity days, the spot-market holder may have to reduce the buy- or the sell-orders, which means that closing out partially happens later in the day (in the *Corbeille* tier) or even the next day (in the *parket* market). The additional uncertainty surely lowers expected returns (as the price discrepancy should have faded away even more, one or two days later) and adds risk. The second reason why the results are too optimistic is that we have ignored a second potential cost that is price pressure. We assume that our trades, which could occasionally be as large as BEF 10m (*i.e.* approximate 250,000 Euros) for one stock, can always be executed at the day's price, without having to 'climb' or 'descend' further into the limit-order book. For low-volume stocks, the average turnover in the spot market per day is, in fact, BEF 717841.7, compared to which a single order of BEF 10m is non-trivial. In that light, our current conclusion that there are no low-risk arbitrage opportunities is conservative.

A second finding is that there is an asymmetry: negative premiums are rarer at all levels, and they unexpectedly often get reversed. A possible explanation is advanced in the next section.

3.3 A Tentative Interpretation of the Sign-related Asymmetry

In this subsection, we provide a tentative interpretation of why we have autocorrelation and why the pattern is asymmetric. Our avenue is that there might be other sources of friction or costs than just pure time value, like issues in going short or in funding long positions.

Problems in shorting in the spot market could provide one possible explanation of why price discrepancies persist. If shorting is difficult or impossible, then, spot prices would be slower to react to bad news than forward prices, where shorting is very easy. Thus, upon bad news, the ratio of forward over spot prices would be temporarily depressed, meaning that negative p's would tend to persist for some time. Positive p's, in contrast, should disappear overnight as buying spot is, in that narrative, no more difficult than buying forward.

We might also consider the opposite friction: maybe shorting stocks is not so often the problem, but finding cash is. If many agents are fully invested and few of them have arranged credit lines, then, upon good news, many agents would prefer to buy forward rather than spot, thus creating positive forward premiums that could persist if prices do not fully adjust within a day. Negative premiums, in contrast, would arise just by accident and tend to disappear fast.[21]

What the trading rule test results tell us is that the second pattern seems to be dominant, and the first one is only weakly active at best. From Table 9 we know that positive events, with excessively high forward prices, are about 2.5 to 3 times as likely as negative ones. Next, the trading rules tell us that positive events are most persistent. Negative ones are less so, and anomalously often a discount even gets reverted into a positive one the very next day. The phenomenon of conditional autocorrelation is most pronounced with the less active stocks. All this is exactly the opposite of what one would expect when shorting is systematically difficult. Clearly, then, a desire to economize on cash, if anything, seems to be at the root of the persistent discrepancies. In a setting where, sufficiently often, the marginal agents are cash-strapped, buyers would prefer the forward market while sellers would go for a spot sale. This would then imply patterns of persistently high forward prices relative to spot values. It would also explain why these occurrences are so much more frequent than instances of very low prices, even to the extent that also negative premiums are followed by positive ones more often than one would expect on a random basis.

4 Conclusions

In perfect, quote-driven markets, a spot and a forward price should differ (only) because of time-to-settlement differences and each return series itself should also contain its own time-value effects. In a market where prices are set via a call rather than quoted by market makers, price differences are also bound to arise because of unexpected imbalances in supply and demand, but any such discrepancies should still be random over time. Empirically, however, both spot and forward tiers of the BSE fail to always reflect the correct time value effect: in the spot tier, the time value effect is insignificant, while in the forward tier the weak traces of time value are limited to low-volume stocks. The settlement effect is very significant in the forward premiums, but even there the estimates remain below our theoretical priors. Nor does the prediction of random deviations hold: unconditionally there is a good dose of positive autocorrelation, but mostly following positive premiums. A trading experiment suggests that predictability is too weak to offer a low-risk positive return, but within those no-arbitrage bounds another factor

[21] The possible impact of 'funding liquidity' issues on prices has been discussed also in the U.S, literature; see *eg* Brunnermeier and Pedersen (2009), Hasbrouck and Seppi (2001), Chordia, Roll, and Subrahmanyam (2005), Coughenour and Saad (2004), Comerton-Forde, Hendershott, Jones, Moulton and Seasholes (2008), Grossman and Vila (1992), and Liu and Longstaff (2004).

seems to be at work. In fact, the pattern suggests that costly shorting of stocks in the spot market is not so much an issue. Rather, problems with quickly raising liquidities could behind most of the autocorrelation. What we see is consistent with a cash scarcity problem, steering buyers to the levered forward market and sellers to the spot tier, rather than with problems in shorting stocks in the cash market.

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Appendix I: Evaluating the Potential Bias in the Time-Value Tests

One possible objection against the standard regression test for time value effects is that true returns should be higher, on average, in periods with high risk-free rates, which would then introduce some correlation between noise and the regressor and hence bias the coefficient upward.

However, due to low variation of the risk-free rate, the bias is negligible, as proven below. In the regression of forward rate $r_{f,t}$ on the time value $\Delta n_{f,t}R_t$, where $\Delta n_{f,t} = (n_{f,t} - n_{f,t-1})$, is

$$r_{f,t} \quad = \quad \alpha + \beta * \Delta n_{f,t}R_t + \rho_t + e_{f,t} - e_{f,t-1}. \tag{19}$$

with $(\rho_t + e_{f,t} - e_{f,t-1})$ being the residual. The bias is introduced by the correlation between the true return ρ_t and the risk-free rate R_t:

$$\begin{aligned} bias = \widehat{\beta} - \beta &= \frac{\text{cov}(r_{f,t}, \Delta n_{f,t}R_t)}{\text{var}(\Delta n_{f,t}R_t)} - \beta \\ &= \frac{\text{cov}(\rho_t, \Delta n_{f,t}R_t)}{\text{var}(\Delta n_{f,t}R_t)} \\ &= \frac{\text{E}(\Delta n_{f,t})}{\text{var}(\Delta n_{f,t}R_t)} * corr(\rho_t, R_t)\sqrt{\text{var}(\rho_t)\text{var}(R_t)} \end{aligned} \tag{20}$$

In the extreme case, *i.e.* $corr(\rho_t, R_t) = 1$, the highest magnitude of bias is $\frac{\text{E}(\Delta n_{f,t})}{\text{var}(\Delta n_{f,t}R_t)} * \sqrt{\text{var}(\rho_t)\text{var}(R_t)}$. We can roughly calculate the following numbers from the data:

$\text{E}(\Delta n_{f,t})$:	-9.640E-04
$\text{var}(\Delta n_{f,t}R_t)$:	1.E-06
$sqrt\,\text{var}(R_t)$:	6.79E-05

So the maximum bias is $-0.65456 * \sqrt{var(\rho_t)}$, with ρ_t being not higher than the observed prices, *i.e.* spot prices. Taking Delhaize stock in the studied period as an example, the standard deviation of the spot prices was 0.012, which makes the maximum bias -0.000785472. This negligible bias makes the interpretation of the OLS estimates in the single-market series plausible.

Table 12: **Overview of Codes for Various Kinds of Prices**

	Missing Codes for Spot Price
AR	buyers reduced
VR	sellers reduced
AA, AC	big buyers reduced‡
AC, VC	big sellers reduced‡
CA	modified buyers price (no transaction)
CP	modified sellers price (no transaction)
CI	indicative price (no transaction)
NC	not quoted (no transaction)
HB	the total turnover contains prolongated (rolled-over) trades turnover†
	Missing Codes for Spot Price
*	settlement price at 2 p.m. (on prolongation days) †
H, H	the total turnover contains reported trades turnover
N, NC	not quoted

Key:
†: *Prolongations* (*deport, report*) are roll-overs at the end of the *quinzaine*, arranged centrally on the day of the *prolongations*. See footnote, section 1.3.
‡: One or a few orders were unusually large, and only those were reduced. In the normal case, all orders share the reduction.

Appendix II: Further Data Description

Table 13: **Details on Data Availability: Spot Market - 1**

Market turnover ranking	Market turnover group	Relative volume ranking	Relative volume group	Company Name	ISIN	Start	End	Sample_obs	No Missing	Missing	AA	AC	AR	AV	CA	CI	CP	HB	NC	VC	VR
1	L	1	L	Andre Dum T.V	BE0003242410	03/01/89	12/28/89	258	203	55	0	0	0	0	1	0	0	0	41	0	0
2	L	24	L	Electrafina_VV_na	BE0380128828	8/18/94	6/22/95	221	168	53	0	0	0	0	0	0	0	0	44	0	0
3	L	49	H	Sidro_T	BE0003109056	03/01/89	12/30/96	2085	1941	144	6	1	0	2	0	0	0	0	32	0	0
4	L	4	L	Monc-Zolder_T	BE0003262616	09/01/89	12/30/96	2081	1840	241	0	1	0	0	1	5	0	1	134	1	0
5	L	25	M	Asturienne_FV_T	BE0005066221	02/01/89	12/30/96	2086	1631	455	6	2	0	2	1	2	1	2	336	0	0
6	L	35	M	Franki_NV	BE0003314169	03/01/89	6/19/96	1947	1728	219	2	0	1	1	6	4	3	0	105	0	0
7	L	12	L	Mosane_(a)	BE0003613248	7/19/89	6/30/95	1553	1355	198	2	1	0	0	0	1	0	0	111	0	0
8	L	17	L	Finoutremert	BE0003045383	03/01/89	6/19/96	1947	1738	209	0	0	0	0	0	0	0	0	110	0	0
9	L	22	L	CFE	BE0003310126	03/01/89	6/19/96	1947	1738	209	2	0	0	6	1	1	1	0	100	0	0
10	L	15	L	Electrafina_VV	BE0005217766	02/01/89	08/05/96	1918	1789	129	0	2	0	0	0	3	0	0	19	0	0
11	L	18	L	Electrorail_T	BE0003031243	03/01/89	12/30/96	2085	1136	949	4	2	0	3	17	7	18	0	793	0	0
12	L	5	L	Mosane_V	BE0003513216	02/01/89	12/21/90	515	460	55	2	0	0	0	0	0	0	0	30	0	0
13	L	61	H	Befimmo_sicafi(Bel-EF)	BE0003678894	12/20/95	6/19/96	131	117	14	0	0	0	0	0	0	0	0	5	1	0
14	L	39	M	FN(bev.a)	BE0003607182	5/23/89	12/27/96	1984	670	1314	24	5	13	8	163	3	183	0	810	1	7
15	L	16	L	Recticel(gew)	BE0003656676	02/01/89	6/19/96	1948	1717	231	0	1	0	2	2	1	1	0	123	0	0
16	L	9	L	FN_(a)	BE0003171676	03/01/89	12/30/96	2085	882	1203	13	8	10	2	175	5	196	0	680	3	6
17	L	27	M	Asturienne_T	BE0003499077	02/01/89	12/30/96	2086	1849	237	10	0	0	6	1	1	0	1	114	1	0
18	L	55	H	Spector	BE0003663748	03/11/93	6/19/96	686	582	104	0	0	0	0	0	1	0	0	69	2	0
19	L	36	M	GBL_VV	BE0005204632	02/01/89	08/05/96	1918	1750	168	10	7	0	0	0	2	0	0	166	0	0
20	L	69	H	Confinimmo	BE0003593044	02/01/89	6/19/96	1948	1655	293	1	2	0	1	1	1	0	0	187	0	1
21	L	33	M	Fortis_AG_VV	BE0005225843	5/23/91	07/03/96	1251	1063	188	1	0	0	0	0	0	0	0	131	0	0
22	L	34	M	Belcofi_T	BE0003603140	03/01/89	6/19/96	1947	1827	120	0	0	0	0	0	1	0	0	20	0	0
23	L	30	M	Desimpel	BE0003634459	01/06/90	5/30/96	1565	1306	259	2	1	0	3	1	2	0	0	171	1	0
24	L	13	L	Powerfin_VV	BE0005216750	02/01/89	08/05/96	1918	1761	157	1	1	0	2	0	0	0	0	141	0	0
25	M	70	H	Glaverbel_vv	BE0005222816	11/22/94	06/06/95	141	65	76	0	0	0	0	0	2	0	0	70	0	0
26	M	43	M	Cla_BECQ	BE0003134302	03/01/89	06/12/96	2069	1877	192	12	2	0	4	9	2	5	0	68	1	0
27	M	10	L	Gen_Bank_vv	BE0005200598	02/01/89	10/04/96	1898	1776	122	8	0	0	0	0	0	0	1	95	1	0
28	M	2	L	Intercom_FV2_T	BE0005062188	02/01/89	6/30/92	912	750	162	0	0	0	0	0	0	0	0	111	0	0
29	M	52	H	Imm_Venn_Belg_T	BE0003599108	03/01/89	6/19/96	1947	1623	324	1	0	0	0	3	1	0	0	220	0	0
30	M	72	H	Nat_Portef	BE0003053460	03/01/89	6/19/96	1947	1737	210	9	4	0	5	0	1	0	0	89	2	0
31	M	40	M	Deceuninck_T	BE0003553618	02/01/89	6/19/96	1948	1790	158	0	0	1	0	1	1	0	0	55	0	0
32	M	3	L	Intercom_FV_T	BE0005007605	03/01/89	6/30/92	911	768	143	1	0	0	0	0	0	0	0	91	0	0
33	M	48	M	Ackermans	BE0003645562	03/01/89	6/19/96	1947	1807	140	5	1	4	3	0	2	1	0	21	0	3
34	M	38	M	Cobepa	BE0003673846	03/01/89	6/19/96	1947	1816	131	6	2	0	1	0	1	0	0	21	1	0
35	M	42	M	Tractebel_vv	BE0005203626	03/06/94	08/05/96	504	442	62	0	1	0	0	0	0	0	0	40	0	0
36	M	60	H	Recticel(bev)	BE0003657682	4/20/89	6/19/96	1870	1623	247	1	0	0	3	0	0	2	0	143	0	0

Table 14: **Details on Data Availability: Spot Market - cont'd**

Market turnover		Relative volume		Company Name	ISIN	Start	End	Sample_obs	No Missing	Missing	Codes for Missing Spot Prices										
ranking	group	ranking	group								AA	AC	AR	AV	CA	CI	CP	HB	NC	VC	VR
37	M	19	L	Electrafina_T	BE0003107035	03/01/89	12/30/91	780	721	59	3	0	0	0	0	0	0	0	12	0	0
38	M	37	M	Quick_Restaurants	BE0003662732	12/07/93	6/19/96	768	730	38	0	2	0	0	0	0	0	0	0	1	0
39	M	23	L	Sofina_T	BE0003491967	03/01/89	6/19/96	1947	1830	117	1	5	0	0	0	0	0	0	13	1	0
40	M	32	M	Gevaert	BE0003623346	03/01/89	6/19/96	1947	1833	114	4	8	0	0	0	0	0	0	2	0	0
41	M	11	L	Electrabel_vv	BE0005202610	02/01/89	4/23/96	1907	1802	105	1	3	0	0	0	0	0	0	2	1	0
42	M	20	L	NMKN	BE0003009025	02/01/89	05/12/95	1807	1628	179	2	3	3	2	4	1	2	0	87	0	0
43	M	59	H	Glaverbel_T	BE0003578862	02/01/89	6/19/96	1948	1716	232	17	3	0	3	0	0	0	0	111	1	0
44	M	46	M	Wagons-lits_T	BE0003432375	04/01/89	7/26/95	1711	1277	434	0	1	0	3	4	4	4	0	334	0	0
45	M	21	L	Electrafina_T	BE0003616274	02/01/89	6/19/96	1948	1832	116	6	3	1	0	0	0	0	0	6	0	0
46	M	31	M	Powerfin_T	BE0003638492	02/01/89	6/19/96	1948	1798	150	5	1	0	1	0	0	0	0	44	0	0
47	M	51	H	Tessenderlo_T	BE0003555639	02/01/89	6/19/96	1948	1825	123	0	0	0	0	0	1	0	0	21	1	0
48	M	6	L	Met_Hob_Ov_T	BE0003200962	03/01/89	12/30/91	780	690	90	0	0	0	0	1	0	0	0	46	0	0
49	H	8	L	Tabacofina_T	BE0003428332	03/01/89	6/30/89	129	118	11	0	0	0	0	0	0	0	0	5	0	0
50	H	65	H	Royale_B	BE0003560688	02/01/89	03/07/96	1958	1847	111	2	7	0	1	0	0	0	0	1	0	0
51	H	28	M	Barco_NV	BE0003614253	5/17/89	6/19/96	1851	1734	117	2	0	0	0	0	1	1	0	21	0	0
52	H	71	H	CMB	BE0003648590	02/01/89	03/07/96	1958	1836	122	2	0	0	2	0	1	3	0	15	0	0
53	H	26	M	Cockerill-Sam(bev)	BE0003543510	02/01/89	03/07/96	1958	1668	290	49	12	0	7	0	1	0	0	122	2	0
54	H	66	H	Colruyt	BE0003523314	02/01/89	03/07/96	1958	1816	142	13	5	0	8	0	0	1	0	16	1	0
55	H	58	H	GBL_T	BE0003494029	03/01/89	03/07/96	1957	1817	140	12	16	0	1	0	0	0	0	12	1	0
56	H	7	L	Intercom_T	BE0003124204	03/01/89	6/30/92	911	832	79	1	0	0	0	0	0	0	0	27	0	0
57	H	45	M	Tractebel_T	BE0003558666	02/01/89	03/07/96	1958	1811	147	13	6	0	0	0	0	0	0	28	1	0
58	H	64	H	ACEC_UM_T	BE0003626372	03/01/89	03/07/96	1957	1842	115	2	1	0	0	0	0	0	0	9	2	0
59	H	29	M	BBL	BE0003647584	02/01/89	03/07/96	1958	1852	106	0	0	0	1	0	1	0	0	3	0	0
60	H	63	H	GIB(GB-Inno-BM)	BE0003576841	02/01/89	03/07/96	1958	1851	107	4	1	0	0	0	0	0	0	6	0	0
61	H	68	H	CBR(BUI_EF)	BE0003681922	03/01/89	03/07/96	1957	1845	112	4	2	0	0	0	0	0	0	9	0	0
62	H	62	H	UCB_T	BE0003235349	03/01/89	03/07/96	1957	1794	163	42	1	0	1	0	0	0	0	21	0	0
63	H	67	H	Bekaert_T	BE0015042071	03/01/89	03/07/96	1957	1819	138	0	2	0	0	0	0	0	0	36	0	0
64	H	50	H	AG	BE0003643542	02/01/89	03/07/96	1958	1804	154	20	0	0	0	0	1	1	0	32	0	0
65	H	53	H	Gen_Mij_T	BE0003619302	04/07/89	03/07/96	1827	1691	136	27	4	0	0	0	0	0	0	9	2	0
66	H	14	L	Tiense_Suiker_r_T	BE0003577856	02/01/89	12/28/90	520	334	186	9	0	0	2	0	0	0	0	147	0	0
67	H	54	H	KredietBank	BE0003565737	02/01/89	03/07/96	1958	1858	100	1	0	0	1	0	0	0	2	0	0	0
68	H	44	M	Gen_Bank	BE0003652634	02/01/89	03/07/96	1958	1817	141	29	11	0	0	0	0	0	0	1	0	0
69	H	57	H	Solvay_T	BE0003470755	03/01/89	03/07/96	1957	1720	237	15	3	0	7	0	0	0	0	114	1	0
70	H	56	H	Delhaize	BE0003562700	02/01/89	03/07/96	1958	1854	104	1	1	0	1	0	0	0	0	4	0	0
71	H	47	M	Electrabel_T	BE0003637486	03/01/89	03/07/96	1957	1824	133	15	10	0	1	0	0	0	1	4	0	0
72	H	41	M	Petrofina_T	BE0003564722	02/01/89	03/07/96	1958	1821	137	23	9	0	2	0	0	0	1	5	0	0

Table 15: **Details on Data Availability: Forward Market**

Market turnover		Relative volume		Company Name	ISIN	Start	End	Sample_obs	No Missing	Missing	Codes for Missing Forward Prices		
ranking	group	ranking	group								*	H	N
1	L	1	L	Andre Dum T.V	BE0003242410	02/01/89	9/29/89	195	37	158	10	0	0
2	L	24	L	Electrafina_VV_na	BE0380128828	8/18/94	6/22/95	221	212	9	0	0	0
3	L	49	H	Sidro_T	BE0003109056	02/01/89	6/18/96	1947	1738	209	5	1	0
4	L	4	L	Monc-Zolder_T	BE0003262616	05/07/89	06/01/92	654	584	70	2	0	1
5	L	25	M	Asturienne_FV_T	BE0005066221	02/01/89	06/01/92	786	635	151	6	0	0
6	L	35	M	Franki_NV	BE0003314169	07/01/92	12/30/96	1300	1241	59	0	1	0
7	L	12	L	Mosane_(a)	BE0003613248	7/19/89	11/17/94	1392	1313	79	1	0	0
8	L	17	L	Finoutremert	BE0003045383	02/01/89	12/30/96	2086	1941	145	12	0	8
9	L	22	L	CFE	BE0003310126	4/22/94	12/30/96	702	659	43	0	0	9
10	L	15	L	Electrafina_VV	BE0005217766	02/01/89	08/05/96	1918	561	1357	0	0	0
11	L	18	L	Electrorail_T	BE0003031243	10/10/89	6/19/96	1747	1619	128	1	0	0
12	L	5	L	Mosane_V	BE0003513216	02/01/89	7/18/89	142	136	6	18	0	0
13	L	61	H	Befimmo_sicafi(Bel-EF)	BE0003678894	04/01/96	12/30/96	258	244	14	0	2	3
14	L	39	M	FN(bev.a)	BE0003607182	5/23/89	10/21/91	630	535	95	2	0	0
15	L	16	L	Recticel(gew)	BE0003656676	02/01/89	12/30/96	2086	1966	120	9	0	2
16	L	9	L	FN_(a)	BE0003171676	02/01/89	10/21/91	731	634	97	9	0	2
17	L	27	M	Asturienne_T	BE0003499077	02/01/89	06/01/92	786	710	76	6	0	0
18	L	55	H	Spector	BE0003663748	2/18/94	12/30/96	747	711	36	0	5	2
19	L	36	M	GBL_VV	BE0005204632	02/01/89	08/05/96	1918	1815	103	4	3	0
20	L	69	H	Confinimmo	BE0003593044	4/22/94	12/30/96	702	664	38	0	3	7
21	L	33	M	Fortis_AG_VV	BE0005225843	10/03/92	07/03/96	1043	995	48	0	0	0
22	L	34	M	Belcofi_T	BE0003603140	10/10/89	12/30/96	1885	1785	100	0	1	0
23	L	30	M	Desimpel	BE0003634459	2/18/94	3/21/96	545	516	29	0	0	0
24	L	13	L	Powerfin_VV	BE0005216750	02/01/89	08/05/96	1918	1804	114	11	3	0
25	M	70	H	Glaverbel_vv	BE0005222816	02/12/94	08/06/95	135	128	7	0	0	0
26	M	43	M	Cla_BECQ	BE0003134302	02/01/89	6/19/96	1948	1819	129	6	0	0
27	M	10	L	Gen_Bank_vv	BE0005200598	07/06/90	10/04/96	1525	1433	92	0	0	0
28	M	2	L	Intercom_FV2_T	BE0005062188	02/01/89	07/12/90	505	470	35	2	0	0
29	M	52	H	Imm_Venn_Belg_T	BE0003599108	10/10/89	12/30/96	1885	1782	103	0	1	1
30	M	72	H	Nat_Portef	BE0003053460	02/01/89	12/30/96	2086	1979	107	12	2	0
31	M	40	M	Deceuninck_T	BE0003553618	10/10/89	12/30/96	1885	1786	99	1	2	1
32	M	3	L	Intercom_FV_T	BE0005007605	02/01/89	07/12/90	505	472	33	3	0	0
33	M	48	M	Ackermans	BE0003645562	09/02/95	12/30/96	493	471	22	0	2	1
34	M	38	M	Cobepa	BE0003673846	02/01/89	12/30/96	2086	1979	107	2	5	0
35	M	42	M	Tractebel_vv	BE0005203626	01/07/94	08/05/96	484	464	20	0	1	0
36	M	60	H	Recticel(bev)	BE0003657682	4/20/89	12/30/96	2008	1897	111	0	0	1

Table 16: **Details on Data Availability: Forward Market - cont'd**

Market turnover		Relative volume		Company Name	ISIN	Start	End	Sample_obs	No Missing	Missing	Codes for Missing Forward Prices		
ranking	group	ranking	group								*	H	N
37	M	19	L	Electrafina_T	BE0003107035	02/01/89	03/07/89	131	124	7	19	0	1
38	M	37	M	Quick_Restaurants	BE0003662732	1/21/94	12/30/96	767	734	33	0	0	0
39	M	23	L	Sofina_T	BE0003491967	02/01/89	12/30/96	2086	1979	107	1	3	0
40	M	32	M	Gevaert	BE0003623346	02/01/89	12/30/96	2086	1979	107	21	2	0
41	M	11	L	Electrabel_vv	BE0005202610	02/01/89	4/23/96	1907	1808	99	0	1	0
42	M	20	L	NMKN	BE0003009025	4/22/94	11/30/95	420	397	23	0	2	0
43	M	59	H	Glaverbel_T	BE0003578862	02/01/89	12/30/96	2086	1977	109	2	2	0
44	M	46	M	Wagons-lits_T	BE0003432375	02/01/89	06/01/92	786	732	54	18	0	0
45	M	21	L	Electrafina_T	BE0003616274	02/01/89	12/30/96	2086	1978	108	7	1	0
46	M	31	M	Powerfin_T	BE0003638492	02/01/89	12/30/96	2086	1978	108	10	3	0
47	M	51	H	Tessenderlo_T	BE0003555639	02/01/89	12/30/96	2086	1978	108	3	4	0
48	M	6	L	Met_Hob_Ov_T	BE0003200962	02/01/89	2/19/90	296	276	20	15	0	0
49	H	8	L	Tabacofina_T	BE0003428332	02/01/89	4/19/89	78	69	9	9	0	14
50	H	65	H	Royale_B	BE0003560688	06/03/90	12/30/96	1780	1690	90	0	121	0
51	H	28	M	Barco_NV	BE0003614253	04/07/89	12/30/96	1955	1853	102	0	9	0
52	H	71	H	CMB	BE0003648590	08/10/91	12/30/96	1365	1301	64	0	123	0
53	H	26	M	Cockerill-Sam(bev)	BE0003543510	02/01/89	12/30/96	2086	1977	109	10	119	0
54	H	66	H	Colruyt	BE0003523314	05/07/90	12/30/96	1693	1609	84	0	120	0
55	H	58	H	GBL_T	BE0003494029	02/01/89	12/30/96	2086	1979	107	3	121	0
56	H	7	L	Intercom_T	BE0003124204	02/01/89	07/12/90	505	473	32	3	0	0
57	H	45	M	Tractebel_T	BE0003558666	02/01/89	12/30/96	2086	1979	107	3	124	0
58	H	64	H	ACEC_UM_T	BE0003626372	02/01/89	12/30/96	2086	1975	111	9	122	0
59	H	29	M	BBL	BE0003647584	07/05/92	12/30/96	1213	1157	56	0	120	0
60	H	63	H	GIB(GB-Inno-BM)	BE0003576841	02/01/89	12/30/96	2086	1979	107	0	125	0
61	H	68	H	CBR(BUI_EF)	BE0003681922	02/01/89	12/30/96	2086	1978	108	3	125	0
62	H	62	H	UCB_T	BE0003235349	02/01/89	12/30/96	2086	1979	107	1	122	0
63	H	67	H	Bekaert_T	BE0015042071	04/04/89	12/30/96	2020	1915	105	1	126	0
64	H	50	H	AG	BE0003643542	06/03/90	12/30/96	1780	1689	91	0	123	0
65	H	53	H	Gen_Mij_T	BE0003619302	04/07/89	12/30/96	1955	1854	101	0	122	0
66	H	14	L	Tiense_Suiker_r_T	BE0003577856	02/01/89	3/19/90	316	298	18	3	0	0
67	H	54	H	KredietBank	BE0003565737	07/05/92	12/30/96	1213	1159	54	0	129	0
68	H	44	M	Gen_Bank	BE0003652634	07/06/90	12/30/96	1713	1629	84	0	123	0
69	H	57	H	Solvay_T	BE0003470755	02/01/89	12/30/96	2086	1979	107	2	126	0
70	H	56	H	Delhaize	BE0003562700	07/03/89	12/30/96	2040	1933	107	0	124	0
71	H	47	M	Electrabel_T	BE0003637486	02/01/89	12/30/96	2086	1979	107	5	132	0
72	H	41	M	Petrofina_T	BE0003564722	02/01/89	12/30/96	2086	1979	107	6	123	0

Table 17: **Details on Data Availability: Merged Spot-Forward sample**

Market turnover		Relative volume										Codes for Missing Prices													
												Spot											Forward		
ranking	group	ranking	group	Company Name	ISIN	Start	End	Sample_obs	No Missing both S & F	Miss S, No Miss F	Miss F, No Miss S	AA	AC	AR	AV	CA	CI	CP	HB	NC	VC	VR	*	H	N
1	L	1	L	Andre Dum T.V	BE0003242410	03/01/89	9/29/89	194	36	1	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0
2	L	24	L	Electrafina_VV_na	BE0380128828	8/18/94	6/22/95	221	168	44	44	0	0	0	0	0	0	0	0	44	0	0	0	0	0
3	L	49	H	Sidro_T	BE0003109056	03/01/89	6/18/96	1946	1718	20	19	6	1	0	2	0	0	0	0	12	0	0	5	1	0
4	L	4	L	Monc-Zolder_T	BE0003262616	05/07/89	06/01/92	654	548	36	36	0	0	0	0	0	0	0	0	37	0	0	2	0	1
5	L	25	M	Asturienne_FV_T	BE0005066221	02/01/89	06/01/92	786	592	43	43	0	0	0	0	1	0	1	0	68	0	0	6	0	0
6	L	35	M	Franki_NV	BE0003314169	07/01/92	6/19/96	1162	1042	199	66	1	0	0	1	0	0	0	0	64	0	0	0	0	0
7	L	12	L	Mosane_(a)	BE0003613248	7/19/89	11/17/94	1392	1219	94	94	2	1	0	0	0	0	0	0	91	0	0	1	0	0
8	L	17	L	Finoutremert	BE0003045383	03/01/89	6/19/96	1947	1708	233	107	0	0	0	0	0	0	0	0	109	0	0	11	0	0
9	L	22	L	CFE	BE0003310126	4/22/94	6/18/96	563	466	193	69	0	0	0	0	0	1	0	0	68	0	0	0	0	0
10	L	15	L	Electrafina_VV	BE0005217766	02/01/89	08/05/96	1918	537	24	24	0	2	0	0	0	3	0	0	19	0	0	0	0	0
11	L	18	L	Electrorail_T	BE0003031243	10/10/89	6/19/96	1747	823	796	796	4	2	0	3	16	7	16	0	763	0	0	1	0	0
12	L	5	L	Mosane_V	BE0003513216	02/01/89	7/18/89	142	135	1	1	1	0	0	0	0	0	0	0	0	0	0	18	0	0
13	L	61	H	Befimmo_sicafi(Bel-EF)	BE0003678894	04/01/96	6/19/96	120	108	136	6	0	0	0	0	0	0	0	0	5	1	0	0	0	0
14	L	39	M	FN(bev.a)	BE0003607182	5/23/89	10/21/91	630	448	87	87	4	0	0	3	5	1	8	0	91	0	1	2	0	0
15	L	16	L	Recticel(gew)	BE0003656676	02/01/89	6/19/96	1948	1706	260	129	0	1	0	2	2	1	1	0	123	0	0	9	0	0
16	L	9	L	FN_(a)	BE0003171676	03/01/89	10/21/91	730	593	41	40	2	0	2	1	4	2	1	0	36	0	1	8	0	2
17	L	27	M	Asturienne_T	BE0003499077	02/01/89	06/01/92	786	694	16	16	0	0	0	0	1	0	0	0	16	0	0	6	0	0
18	L	55	H	Spector	BE0003663748	2/18/94	6/19/96	609	510	201	70	0	0	0	0	0	1	0	0	67	2	0	0	1	0
19	L	36	M	GBL_VV	BE0005204632	02/01/89	08/05/96	1918	1743	72	72	10	7	0	0	0	2	0	0	166	0	0	4	3	0
20	L	69	H	Confinimmo	BE0003593044	4/22/94	6/19/96	564	453	211	85	0	2	0	0	0	0	0	0	81	0	0	0	0	0
21	L	33	M	Fortis_AG_VV	BE0005225843	11/03/92	07/03/96	1042	872	123	123	1	0	0	0	0	0	0	0	121	0	0	0	0	0
22	L	34	M	Belcofi_T	BE0003603140	10/10/89	6/19/96	1747	1632	153	20	0	0	0	0	0	0	0	0	20	0	0	0	0	0
23	L	30	M	Desimpel	BE0003634459	2/18/94	3/13/96	539	449	67	67	0	0	0	0	0	1	0	0	71	0	0	0	0	0
24	L	13	L	Powerfin_VV	BE0005216750	02/01/89	08/05/96	1918	1744	60	60	1	1	0	2	0	0	0	0	141	0	0	11	3	0
25	M	70	H	Glaverbel_vv	BE0005222816	02/12/94	06/06/95	133	58	70	68	0	0	0	0	0	1	0	0	69	0	0	0	0	0
26	M	43	M	Cla_BECQ	BE0003134302	03/01/89	6/19/96	1947	1769	50	49	11	2	0	4	2	2	1	0	28	1	0	6	0	0
27	M	10	L	Gen_Bank_vv	BE0005200598	07/06/90	10/04/96	1525	1406	27	27	8	0	0	0	0	0	0	0	89	0	0	0	0	0
28	M	2	L	Intercom_FV2_T	BE0005062188	02/01/89	07/12/90	505	460	10	10	0	0	0	0	0	0	0	0	13	0	0	2	0	0
29	M	52	H	Imm_Venn_Belg_T	BE0003599108	10/10/89	6/19/96	1747	1434	348	216	1	0	0	0	1	0	0	0	215	0	0	0	1	0
30	M	72	H	Nat_Portef	BE0003053460	03/01/89	6/19/96	1947	1733	246	112	9	4	0	5	0	1	0	0	89	2	0	12	2	0
31	M	40	M	Deceuninck_T	BE0003553618	10/10/89	6/19/96	1747	1606	180	48	0	0	0	0	0	1	0	0	45	0	0	1	1	0
32	M	3	L	Intercom_FV_T	BE0005007605	03/01/89	07/12/90	504	456	16	15	1	0	0	0	0	0	0	0	17	0	0	3	0	0
33	M	48	M	Ackermans	BE0003645562	09/02/95	6/19/96	355	336	135	3	3	1	4	0	0	0	1	0	12	0	3	0	0	0

Table 18: **Details on Data Availability: Merged Spot-Forward sample - cont'd**

Market turnover		Relative volume		Company Name	ISIN	Start	End	Sample_obs	No Missing both S & F	Miss S, No Miss F	Miss F, No Miss S	Codes for Missing Prices													
												Spot											Forward		
ranking	group	ranking	group									AA	AC	AR	AV	CA	CI	CP	HB	NC	VC	VR	*	H	N
34	M	38	M	Cobepa	BE0003673846	03/01/89	6/19/96	1947	1812	167	33	6	2	0	1	0	1	0	0	21	1	0	2	3	0
35	M	42	M	Tractebel_vv	BE0005203626	01/07/94	08/05/96	484	423	41	41	0	1	0	0	0	0	0	0	39	0	0	0	1	0
36	M	60	H	Recticel(bev)	BE0003657682	4/20/89	6/19/96	1870	1618	279	147	1	0	0	3	0	0	2	0	143	0	0	0	0	0
37	M	19	L	Electrafina_T	BE0003107035	03/01/89	03/07/89	130	123	1	0	0	0	0	0	0	0	0	0	1	0	0	19	0	1
38	M	37	M	Quick_Restaurants	BE0003662732	1/21/94	6/19/96	629	598	136	3	0	1	0	0	0	0	0	0	0	1	0	0	0	0
39	M	23	L	Sofina_T	BE0003491967	03/01/89	6/19/96	1947	1826	153	19	1	5	0	0	0	0	0	0	13	1	0	1	2	0
40	M	32	M	Gevaert	BE0003623346	03/01/89	6/19/96	1947	1829	150	16	4	8	0	0	0	0	0	0	2	0	0	20	1	0
41	M	11	L	Electrabel_vv	BE0005202610	02/01/89	4/23/96	1907	1799	9	9	1	3	0	0	0	0	0	0	2	1	0	0	1	0
42	M	20	L	NMKN	BE0003009025	4/22/94	11/30/95	420	367	30	30	0	2	0	0	0	0	0	0	32	0	0	0	2	0
43	M	59	H	Glaverbel_T	BE0003578862	02/01/89	6/19/96	1948	1711	266	133	17	3	0	3	0	0	0	0	110	1	0	2	1	0
44	M	46	M	Wagons-lits_T	BE0003432375	04/01/89	06/01/92	784	696	36	34	0	0	0	0	0	0	0	0	48	0	0	18	0	0
45	M	21	L	Electrafina_T	BE0003616274	02/01/89	6/19/96	1948	1828	150	17	6	3	1	0	0	0	0	0	5	0	0	7	1	0
46	M	31	M	Powerfin_T	BE0003638492	02/01/89	6/19/96	1948	1794	184	51	5	1	0	1	0	0	0	0	44	0	0	10	2	0
47	M	51	H	Tessenderlo_T	BE0003555639	02/01/89	6/19/96	1948	1822	156	23	0	0	0	0	0	1	0	0	20	1	0	3	3	0
48	M	6	L	Met_Hob_Ov_T	BE0003200962	03/01/89	2/19/90	295	271	5	4	0	0	0	0	0	0	0	0	6	0	0	15	0	0
49	H	8	L	Tabacofina_T	BE0003428332	03/01/89	4/19/89	77	68	1	0	0	0	0	0	0	0	0	0	4	0	0	9	0	14
50	H	65	H	Royale_B	BE0003560688	06/03/90	03/07/96	1652	1555	135	12	2	7	0	0	0	0	0	0	0	0	0	0	101	0
51	H	28	M	Barco_NV	BE0003614253	04/07/89	6/19/96	1817	1698	155	22	2	0	0	0	0	0	0	0	20	0	0	0	2	0
52	H	71	H	CMB	BE0003648590	09/10/91	03/07/96	1236	1170	131	8	2	0	0	2	0	1	3	0	15	0	0	0	102	0
53	H	26	M	Cockerill-Sam(bev)	BE0003543510	02/01/89	03/07/96	1958	1664	313	190	49	12	0	7	0	1	0	0	122	2	0	10	99	0
54	H	66	H	Colruyt	BE0003523314	05/07/90	03/07/96	1565	1446	163	40	13	5	0	7	0	0	0	0	12	1	0	0	99	0
55	H	58	H	GBL_T	BE0003494029	03/01/89	03/07/96	1957	1813	166	42	12	16	0	1	0	0	0	0	12	1	0	3	101	0
56	H	7	L	Intercom_T	BE0003124204	03/01/89	07/12/90	504	467	6	5	1	0	0	0	0	0	0	0	6	0	0	3	0	0
57	H	45	M	Tractebel_T	BE0003558666	02/01/89	03/07/96	1958	1807	172	49	13	6	0	0	0	0	0	0	28	1	0	3	102	0
58	H	64	H	ACEC_UM_T	BE0003626372	03/01/89	03/07/96	1957	1838	137	13	2	1	0	0	0	0	0	0	7	2	0	9	101	0
59	H	29	M	BBL	BE0003647584	07/05/92	03/07/96	1085	1032	125	2	0	0	0	1	0	1	0	0	3	0	0	0	100	0
60	H	63	H	GIB(GB-Inno-BM)	BE0003576841	02/01/89	03/07/96	1958	1847	132	9	4	1	0	0	0	0	0	0	6	0	0	0	104	0
61	H	68	H	CBR(BUI_EF)	BE0003681922	03/01/89	03/07/96	1957	1841	137	13	4	2	0	0	0	0	0	0	9	0	0	2	101	0
62	H	62	H	UCB_T	BE0003235349	03/01/89	03/07/96	1957	1790	189	65	42	1	0	1	0	0	0	0	21	0	0	1	100	0
63	H	67	H	Bekaert_T	BE0015042071	04/04/89	03/07/96	1892	1752	163	40	0	2	0	0	0	0	0	0	36	0	0	1	103	0
64	H	50	H	AG	BE0003643542	06/03/90	03/07/96	1652	1517	172	49	15	0	0	0	0	0	0	0	30	0	0	0	102	0
65	H	53	H	Gen_Mij_T	BE0003619302	04/07/89	03/07/96	1827	1687	167	44	27	4	0	0	0	0	0	0	9	2	0	0	100	0
66	H	14	L	Tiense_Suiker_r_T	BE0003577856	02/01/89	3/19/90	316	275	23	23	9	0	0	2	0	0	0	0	15	0	0	3	0	0

Table 19: **Details on Data Availability: Merged Spot-Forward sample - cont'd**

Market turnover		Relative volume										Codes for Missing Prices													
												Spot											Forward		
ranking	group	ranking	group	Company Name	ISIN	Start	End	Sample_obs	No Missing both S & F	Miss S, No Miss F	Miss F, No Miss S	AA	AC	AR	AV	CA	CI	CP	HB	NC	VC	VR	*	H	N
67	H	54	H	KredietBank	BE0003565737	07/05/92	03/07/96	1085	1033	126	3	1	0	0	0	0	0	0	2	0	0	0	0	105	0
68	H	44	M	Gen_Bank	BE0003652634	07/06/90	03/07/96	1585	1463	166	43	29	11	0	0	0	0	0	0	0	0	0	0	101	0
69	H	57	H	Solvay_T	BE0003470755	03/01/89	03/07/96	1957	1718	261	137	14	3	0	7	0	0	0	0	113	1	0	2	102	0
70	H	56	H	Delhaize	BE0003562700	08/03/89	03/07/96	1911	1804	129	6	1	1	0	1	0	0	0	0	4	0	0	0	102	0
71	H	47	M	Electrabel_T	BE0003637486	03/01/89	03/07/96	1957	1821	158	34	15	10	0	1	0	0	0	1	4	0	0	5	113	0
72	H	41	M	Petrofina_T	BE0003564722	02/01/89	03/07/96	1958	1817	162	39	23	9	0	2	0	0	0	1	5	0	0	6	101	0